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Property Library for Neopentane

FluidEXL*Graphics* with LibC5H12_Neo for Excel®

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Property Library for Neopentane
Including DLL and Add-In for Excel®

FluidEXL*Graphics*
LibC5H12_NEO

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0. Package Contents

0.1 Zip files for 32-bit Office®

The following zip files are delivered for your computer running a 32-bit Office® version.

English zip file "CD_FluidEXL_Graphics_LibC5H12_NEO_Eng.zip" including the following files:

FluidEXL_Graphics_Eng_Setup.exe	- English installation program for the Add-In FluidEXL*Graphics* for use in Excel®
FluidEXL_Graphics_Eng.xla	- English Add-In for FluidEXL*Graphics*
LibC5H12_NEO.dll	- Dynamic Link Library for use in Windows programs
LibC5H12_NEO.hlp	- Help file for the LibC5H12_NEO property library
FluidEXL_Graphics_LibC5H12_NEO_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibC5H12_NEO.zip" including the following files:

FluidEXL_Graphics_Setup.exe	- German installation program for the Add-In FluidEXL*Graphics* for application in Excel®.
FluidEXL_Graphics.xla	- German Add-In for FluidEXL*Graphics*
LibC5H12_NEO.dll	- Dynamic Link Library for use in Windows® programs
LibC5H12_NEO.hlp	- Help file for the LibC5H12_NEO property library
FluidEXL_Graphics_LibC5H12_NEO_Docu_Eng.pdf	- User's Guide

0.2 Zip files for 64-bit Office®

The following zip files are delivered for your computer running a 64-bit Office® version.

English zip file "CD_FluidEXL_Graphics_LibC5H12_NEO_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibC5H12_NEO_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics_Eng.xla	- English FluidEXL*Graphics* Add-In
FluidEXL_Graphics_Eng_64_Setup.msi	- Self-extracting and self-installing program
LibC5H12_NEO.dll	- Dynamic link library for use in Windows® programs
LibC5H12_NEO.hlp	- Help file for the LibC5H12_NEO property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

German zip file "CD_FluidEXL_Graphics_LibC5H12_NEO_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibC5H12_NEO_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics.xla	- German FluidEXL*Graphics* Add-In
FluidEXL_Graphics_64_Setup.msi	- Self-extracting and self-installing program
LibC5H12_NEO.dll	- Dynamic link library for use in Windows® programs
LibC5H12_NEO.hlp	- Help file for the LibC5H12_NEO property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL*Graphics*

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

1. Property Functions

Functional Dependence	Function Name	Call from Fortran Program	Property or Function	Unit of the Result
$a = f(p,t,x)$	a_ptx_C5H12_NEO	A_PTX_C5H12_NEO(P,T,X)	Thermal diffusivity	m²/s
$c_p = f(p,t,x)$	cp_ptx_C5H12_NEO	CP_PTX_C5H12_NEO(P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_C5H12_NEO	CV_PTX_C5H12_NEO(P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\eta = f(p,t,x)$	eta_ptx_C5H12_NEO	ETA_PTX_C5H12_NEO(P,T,X)	Dynamic viscosity	Pa . s
$h = f(p,t,x)$	h_ptx_C5H12_NEO	H_PTX_C5H12_NEO(P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	ka_ptx_C5H12_NEO	KA_PTX_C5H12_NEO(P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lam_ptx_C5H12_NEO	LAM_PTX_C5H12_NEO(P,T,X)	Thermal conductivity	W/(m . K)
$\nu = f(p,t,x)$	ny_ptx_C5H12_NEO	NY_PTX_C5H12_NEO(P,T,X)	Kinematic viscosity	m²/s
$Pr = f(p,t,x)$	pr_ptx_C5H12_NEO	PR_PTX_C5H12_NEO(P,T,X)	*Prandtl*-number	-
$p_s = f(t)$	ps_t_C5H12_NEO	PS_T_C5H12_NEO(T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_C5H12_NEO	RHO_PTX_C5H12_NEO(P,T,X)	Density	kg/m³
$s = f(p,t,x)$	s_ptx_C5H12_NEO	S_PTX_C5H12_NEO(P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_C5H12_NEO	T_PH_C5H12_NEO(P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_C5H12_NEO	T_PS_C5H12_NEO(P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_C5H12_NEO	TS_P_C5H12_NEO(P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_C5H12_NEO	U_PTX_C5H12_NEO(P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_C5H12_NEO	V_PTX_C5H12_NEO(P,T,X)	Specific volume	m³/kg
$w = f(p,t,x)$	w_ptx_C5H12_NEO	W_PTX_C5H12_NEO(P,T,X)	Isentropic speed of sound	m/s

Functional Dependence	Function Name	Call from Fortran Program	Property or Function	Unit of the Result
$x = f(p,h)$	x_ph_C5H12_NEO	X_PH_C5H12_NEO(P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	x_ps_C5H12_NEO	X_PS_C5H12_NEO(P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg

Units:

t in °C
p in bar
x in (kg saturated steam)/(kg wet steam)

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Reference state

h = 0 kJ/kg and s = 0 kJ/(kg K) at p = 1.01325 bar on the saturated liquid line (x = 0)

Details on the vapor fraction *x*

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

Wet-steam region

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for *x*. When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* and *t* and *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in –1.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Note:

If the input values are located outside the range of validity, the calculated function will always result in –1000. Please find more exact details on every function and its corresponding range of validity in the enclosed software documentation in Chapter 3.

2. Application of FluidEXL*Graphics* in Excel®

The FluidEXL*Graphics* Add-In has been developed to calculate thermodynamic properties in Excel more conveniently. Within Excel®, it enables the direct call of functions relating to neopentane from the LibC5H12_NEO property library.

2.1 Installing FluidEXL*Graphics*

If FluidEXL*Graphics* has not yet been installed or if there is a version installed which has been delivered before June 2010, please complete the initial installation procedure described below.

If FluidEXL*Graphics* has already been installed in a version which has been delivered after June 2010, you simply need to copy the files which belong to the LibC5H12_NEO library. In this case, follow the subsection "Adding the LibC5H12_NEO Library" on page 2/11.

Installing FluidEXL*Graphics* for 32-bit Windows®

Complete the following steps for initial installation of FluidEXL*Graphics*. Before you begin, it is best to uninstall any trial version or full version of FluidEXL*Graphics* delivered before June 2010. After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibC5H12_NEO_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibC5H12_NEO.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibC5H12_NEO_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_NEO (for German version of Windows)

in your Windows Explorer, Norton Commander etc. Now, open this folder by double-clicking on it. Within this folder you will see the following files:

FluidEXL_Graphics_Eng_Setup.exe (for English version of Windows)
FluidEXL_Graphics_Setup.exe (for German version of Windows)
FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)
FluidEXL_Graphics_LibC5H12_NEO_Docu_Eng.pdf
LibC5H12_NEO.dll
LibC5H12_NEO.hlp.

In order to run the installation of FluidEXL*Graphics* double-click the file

FluidEXL_Graphics_Eng_Setup.exe (for English version of Windows)
FluidEXL_Graphics_Setup.exe (for German version of Windows).

Installation may start with a window noting that all Windows programs should be closed. When this is the case, the installation can be continued. Click the "Continue" button.

In the following dialog box, "Choose Destination Location", the default path offered automatically for the installation of FluidEXL*Graphics* is

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see figure below).

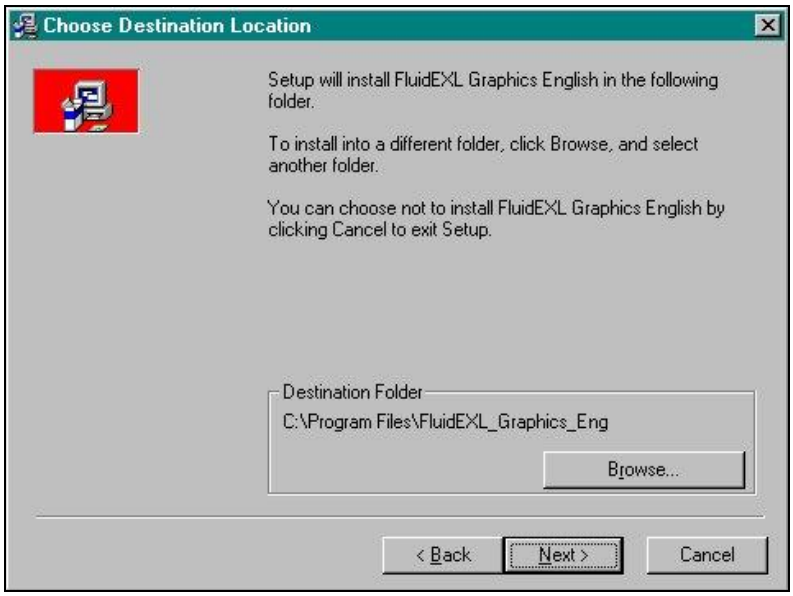

Figure 2.1: Choose Destination Location

Finally, click on "Next" to continue installation; click "Next" again in the "Start Installation" window which follows in order to start the installation of FluidEXL*Graphics*. After FluidEXL*Graphics* has been installed, the sentence

"FluidEXL Graphics English has been successfully installed."

will be shown. Confirm this by clicking the "Finish" button. During the installation process the following files

Advapi32.dll	LC.dll
DFORMD.dll	Msvcp60.dll
Dforrt.dll	Msvcrt.dll
UNWISE.EXE	UNWISE.INI
INSTALL_EXL.LOG	

have been copied into the chosen destination folder, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

In the next step, the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibC5H12_NEO.dll	
LibC5H12_NEO.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibC5H12_NEO_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_NEO	(for German version of Windows)

must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)),

using an appropriate program such as Windows Explorer or Norton Commander.

Installing FluidEXL*Graphics* for 64-bit Windows®

Complete the following steps for initial installation of FluidEXL*Graphics*. Before you begin, it is best to uninstall any trial version or full version of FluidEXL*Graphics* delivered before June 2010. After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibC5H12_Neo_x64_Eng.zip" (for English version of Windows)
"CD_FluidEXL_Graphics_LibC5H12_Neo_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibC5H12_NEO_Eng (for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_NEO (for German version of Windows)

in your Windows Explorer, Norton Commander etc. Now, open this folder by double-clicking on it. Within this folder you will see the following files

FluidEXL_Graphics_LibC5H12_NEO_Docu
FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)
FluidEXL_Graphics_Eng_Setup_64.msi (for English version of Windows)
FluidEXL_Graphics_Setup_64.msi (for German version of Windows)
LibC5H12_NEO.dll
LibC5H12_NEO.hlp
Setup.exe

and the folders

vcredist_x64
WindowsInstaller3_1.

In order to run the installation of FluidEXL*Graphics* double-click the file

Setup.exe.

If the "Microsoft Visual C++ 2010 x64 Redistributable Pack" is not running on your computer yet, installation will start with a window noting that the "Visual C++ 2010 runtime library (x64)" will be installed on your machine (see figure below).

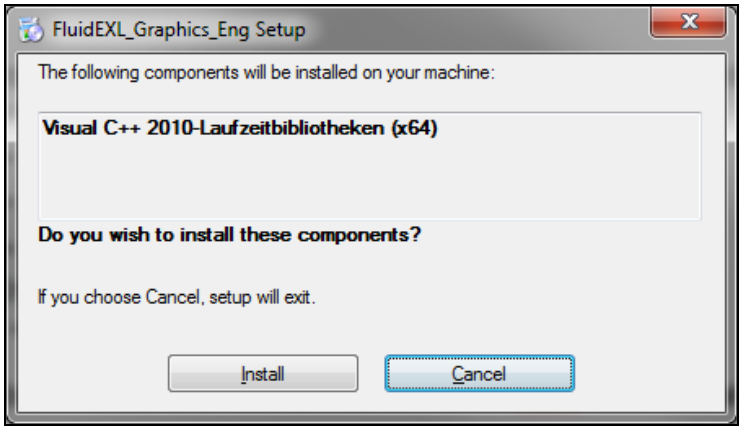

Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

Click on "Install" to continue.

In the following window you are required to accept the Microsoft® license terms to install the "Microsoft Visual C++ 2010 x64 Redistributable Pack" by ticking the box next to "I have read and accept the license terms" (see figure below).

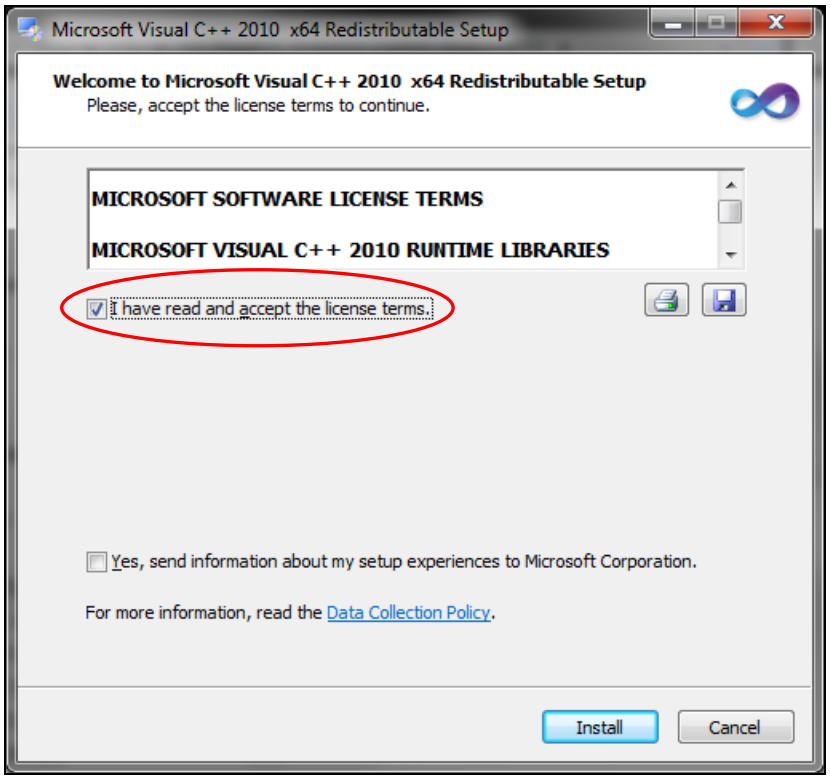

Figure 2.3: Accepting the license terms

Now click on "Install" to continue installation.

After the "Microsoft Visual C++ 2010 x64 Redistributable Pack" has been installed, you will see the sentence "Microsoft Visual C++ 2010 x64 Redistributable has been installed." Confirm this by clicking "Finish."

Now the installation of FluidEXL_Graphics_Eng_64 starts with a window noting that the installer will guide you through the installation. Click the "Next >" button to continue.
In the following dialog box, "Select Installation Folder," the default path offered automatically for the installation of FluidEXL*Graphics* is

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows).
C:\Programme\FluidEXL_Graphics (for German version of Windows).

By clicking the "Browse…" button, you can change the installation directory before installation (see Figure 2.4).

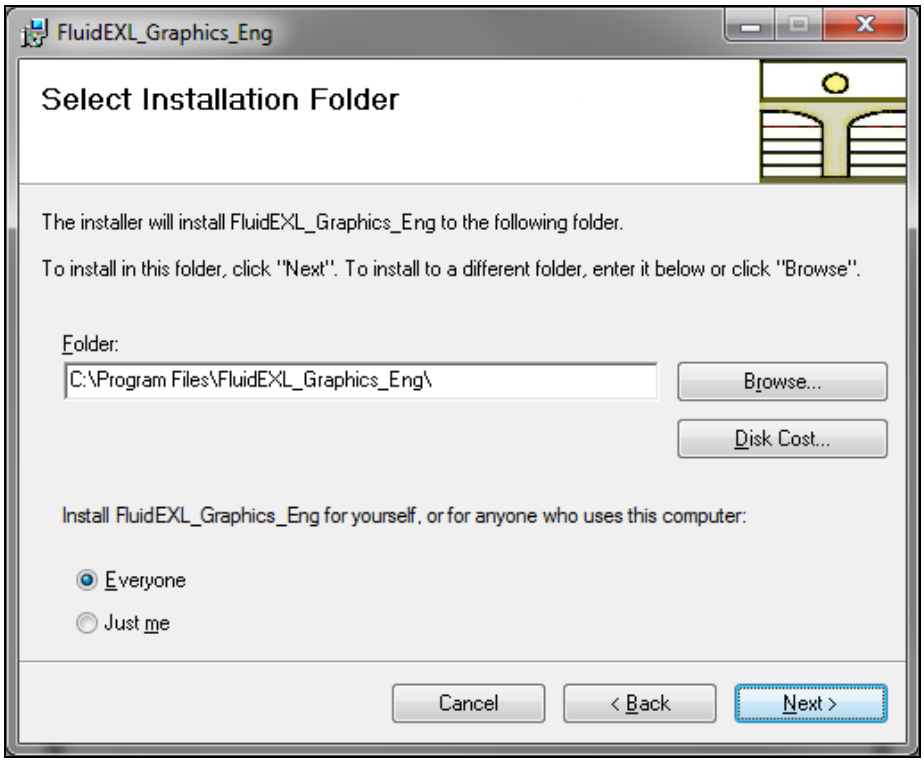

Figure 2.4: Choosing the Installation Folder of FluidEXL*Graphics*

Finally, click on "Next >" to continue installation; click "Next >" again in the "Confirm Installation" window which follows in order to start the installation of FluidEXL*Graphics*.

After FluidEXL*Graphics* has been installed, you will see the sentence "FluidEXL_Graphics_Eng has been successfully installed." Confirm this by clicking the "Close" button.

During the installation process the following files will have been copied into the destination folder chosen, the standard being C:\Program Files\FluidEXL_Graphics_Eng:

capt_ico_big.ico	libmmd.dll
libifcoremd.dll	LC.dll
libiomp5md.dll.	

In addition, the two subdirectories \FORMULATION97 and \FLuft were created in the destination folder.

In the next step, the files below,

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibC5H12_NEO.dll	
LibC5H12_NEO.hlp	

found in your CD folder, must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows))

using an appropriate program such as Explorer or Norton Commander.

2.2 Registering FluidEXL*Graphics* as Add-In in Excel®

Registering FluidEXL*Graphics* as Add-In in Excel®, versions 2003 or earlier

After the installation of FluidEXL*Graphics*, the program must be registered as an Add-In in Excel®. In order to do so, start Excel® and carry out the following steps:

- Click "Tools" in the upper menu bar of Excel®.
- Here, click the "Add-Ins..." menu item.
  After a short delay the "Add-Ins" dialog box will appear.
- Click "Browse...."
- In the following dialog box, choose your chosen destination folder (the standard being

  C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
  C:\Programme\FluidEXL_Graphics (for German version of Windows))

  here select

  "FluidEXL_Graphics_Eng.xla" (for English version of Windows)
  "FluidEXL_Graphics.xla" (for German version of Windows)

  and afterwards click "OK".
- Now, the entry

  "FluidEXL_Graphics_Eng" (for English version of Windows)
  "FluidEXL_Graphics" (for German version of Windows)

  will appear in the Add-Ins list.

Note:
As long as the check box next to the file name "FluidEXL Graphics Eng" is checked, this Add-In will be loaded automatically every time you start Excel® until you unmark the box by clicking on it again.

In order to register FluidEXL*Graphics* as an Add-In, click "OK" in the "Add-Ins" dialog box. Now, the new FluidEXL*Graphics* menu bar will appear in the upper menu area of your Excel® screen, marked with a red circle in Figure 2.5.

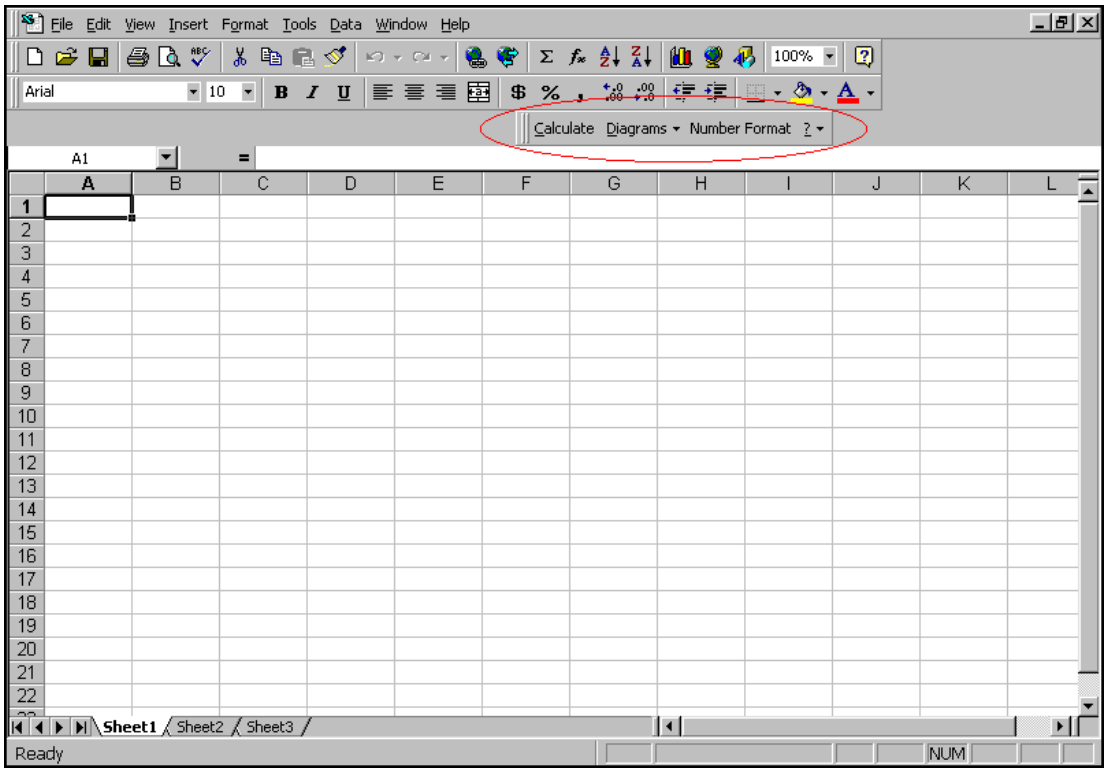

Figure 2.5: Menu bar of FluidEXL*Graphics*

From within Excel you can now select the "LibC5H12_NEO" DLL library property functions via this menu bar (cf. part 2.5 on page 2/19).

Registering FluidEXL*Graphics* as Add-In in Excel® 2007 (or later versions)

After installation in Windows®, FluidEXL*Graphics* must be registered in Excel® versions 2007 and later as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the Windows Office® button in the upper left hand corner of Excel®
- Click on the "Excel Options" button in the menu which appears (see Figure 2.6)

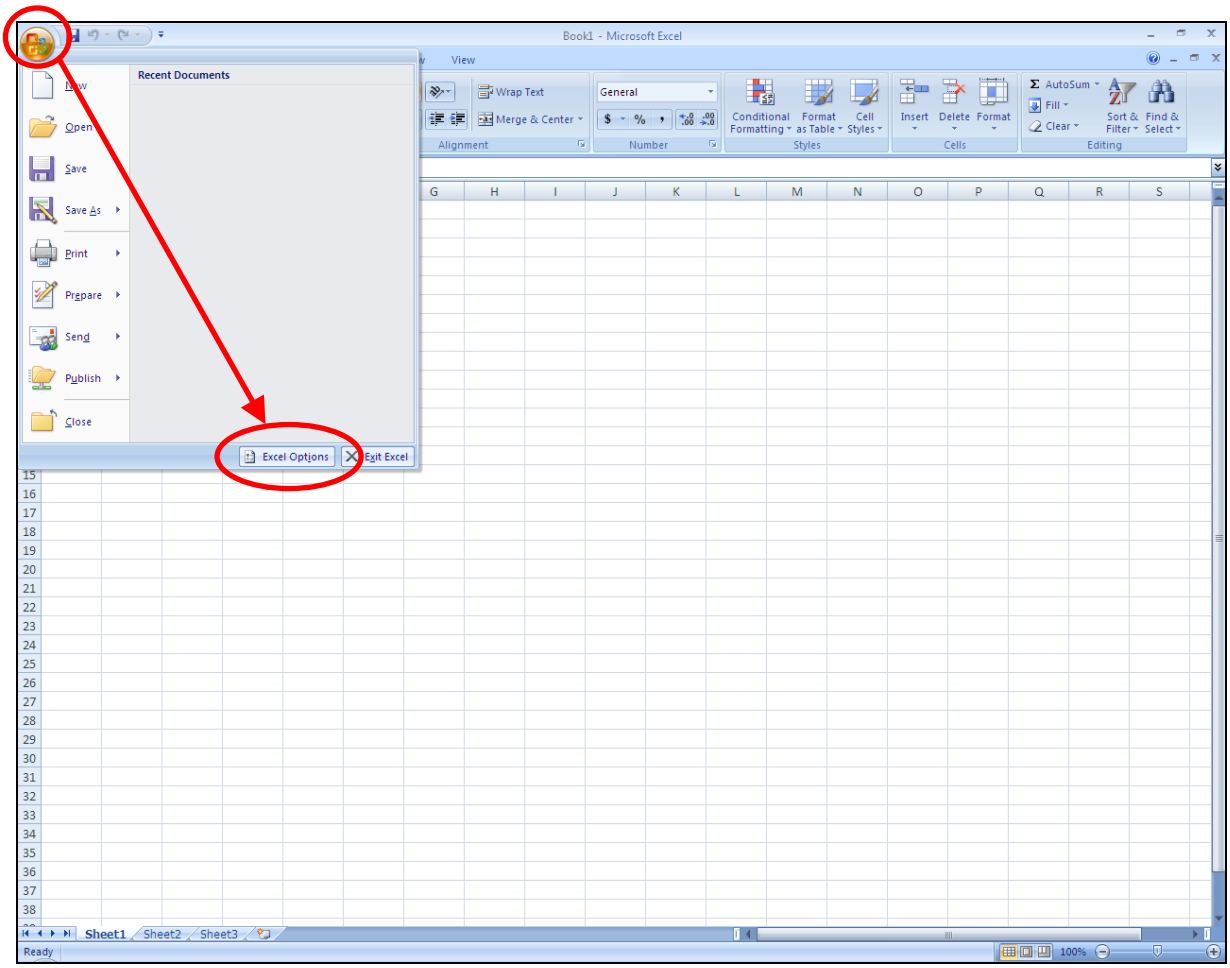

Figure 2.6: Registering FluidEXL*Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

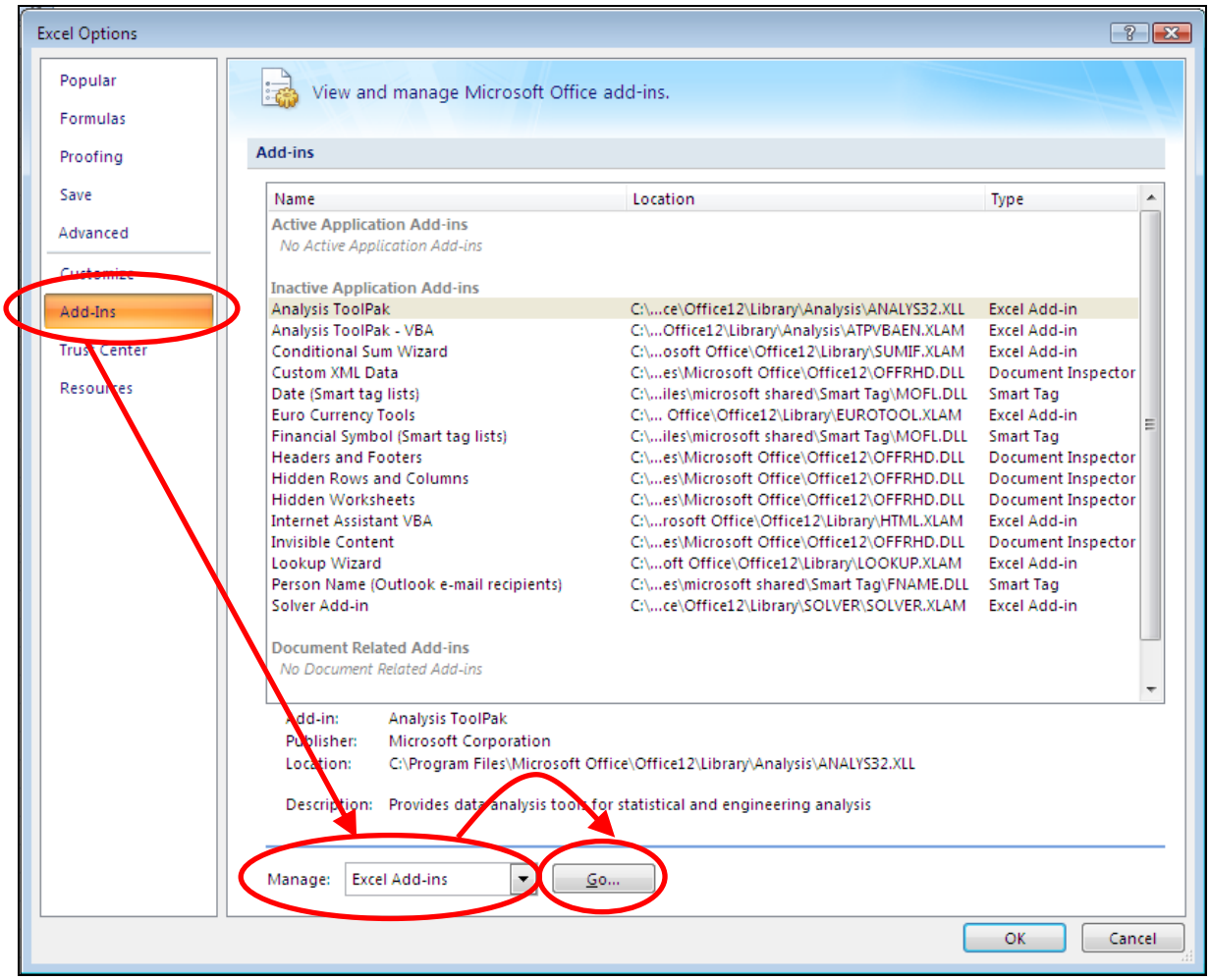

Figure 2.7: Dialog window "Excel Options"

- Should it not be shown in the list automatically, select "Excel Add-ins" (found next to "Manage:" in the lower area of the menu)
- Then click the "Go…" button
- Click "Browse" in the following window and locate the destination folder, generally

  C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
  C:\Programme\FluidEXL_Graphics (for German version of Windows);

  within that folder click on the file named

  "FluidEXL_Graphics_Eng.xla" (for English version of Windows)
  "FluidEXL_Graphics.xla" (for German version of Windows)

  and then hit "OK."

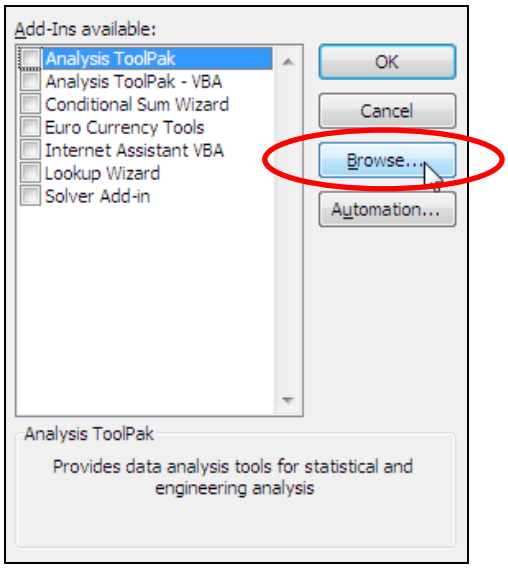

Figure 2.8: Dialog window "Add-Ins available"

- Now, "FluidEXL Graphics Eng" will be shown in your list of Add-Ins.
  (If a check-mark is situated in the box next to the name "FluidEXL Graphics Eng," this Add-In will automatically be loaded whenever Excel® starts. This will continue to occur unless the check-mark is removed from the box by clicking on it.)

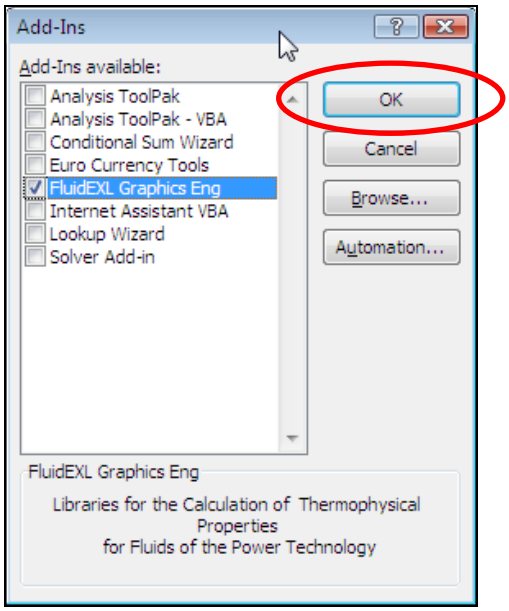

Figure 2.9: Dialog window "Add-Ins"

- In order to register the Add-In click the "OK" button in the "Add-Ins" window.
- In order to use FluidEXL*Graphics* in the following example, click on the menu item "Add-Ins" shown in Figure 2.10.

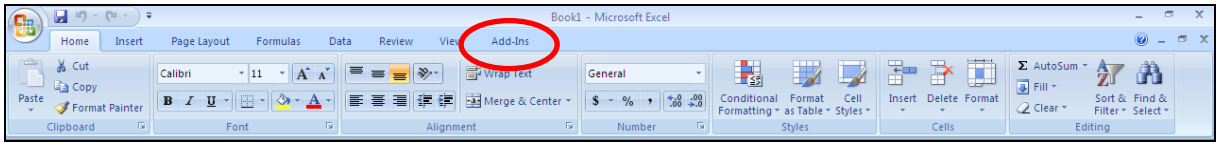

Figure 2.10: Menu item "Add-Ins"

In the upper menu region of Excel, the FluidEXL*Graphics* menu bar will appear as marked with the red circle in the next figure.

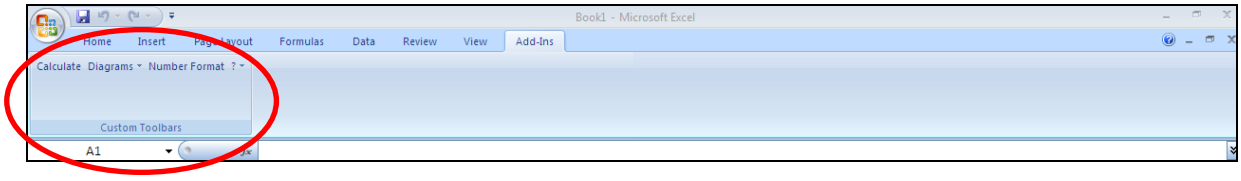

Figure 2.11: FluidEXL*Graphics* menu bar

Installation of FluidEXL*Graphics* in Excel® (versions 2007 and later) is now finished. FluidEXL*Graphics* can be used analogous to the description for using with earlier Excel® versions.

Adding the LibC5H12_NEO Library (FluidEXL*Graphics* is already installed)

If FluidEXL*Graphics* has already been installed in the June 2010 version, you only have to copy the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibC5H12_NEO.dll	
LibC5H12_NEO.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibC5H12_NEO_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibC5H12_NEO	(for German version of Windows)

into the folder you have chosen for the installation of FluidEXL*Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

From within Excel you can now select the "LibC5H12_NEO" DLL library property functions for neopentane via this menu bar (the example calculation can be found in chapter 2.5 on page 2/19).

2.3 The FluidEXL*Graphics* Help System

As mentioned earlier, FluidEXL*Graphics* also provides detailed online help functions. If you are running Windows Vista or Windows 7, please note the paragraph
"Using the FluidEXL*Graphics* Online-Help in Windows Vista or Windows 7."

For general information in Excel® click on "?" and then "Help" in the FluidEXL*Graphics* menu bar. Information on individual property functions may be accessed via the following steps:

- Click "Calculate" in the FluidEXL*Graphics* menu bar.
- Click on the "Neopentane LibC5H12_NEO" library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" button in the lower left-hand edge of the "Insert Function" window.

- If the "Office Assistant" is active, first double-click "Help on this feature" and in the next menu click "Help on selected function".

If the LibC5H12_NEO.hlp function help cannot be found, confirm the question whether you want to look for it yourself with "Yes". Select the LibC5H12_NEO.hlp file in the installation folder of FluidEXL^{Graphics} in the window which is opened, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)

and click "Yes" in order to complete the search.

Using the FluidEXL^{Graphics} Online Help in Windows Vista or Windows 7

If you are running Windows Vista or Windows 7 on your computer, you might not be able to open Help files. To view these files you have to install the Microsoft® Windows Help program which is provided by Microsoft®. Please carry out the following steps in order to download and install the Windows Help program. Open Microsoft Internet Explorer® and go to the following address:

http://support.microsoft.com/kb/917607/

You will see the following web page:

Figure 2.12: Microsoft® Support web page

Scroll down until you see the headline "Resolution." Here you can see the bold hint:

> "Download the appropriate version of Windows Help program (WinHlp32.exe), depending on the operating system that you are using:"

The following description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.13).

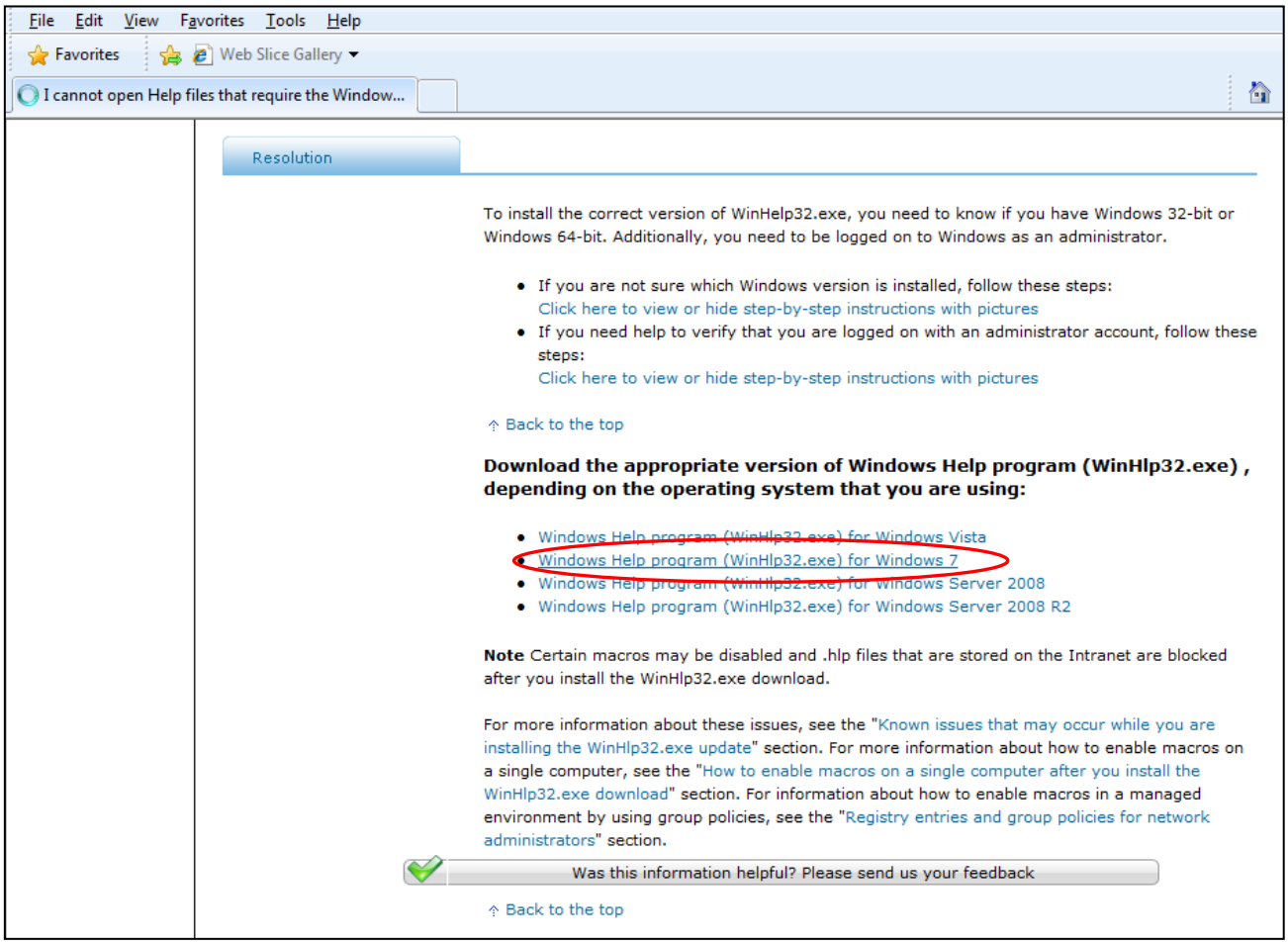

Figure 2.13: Selecting your Windows version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program.

First, a validation of your Windows License is required.

To do this click on the "Continue" button (see Figure 2.14).

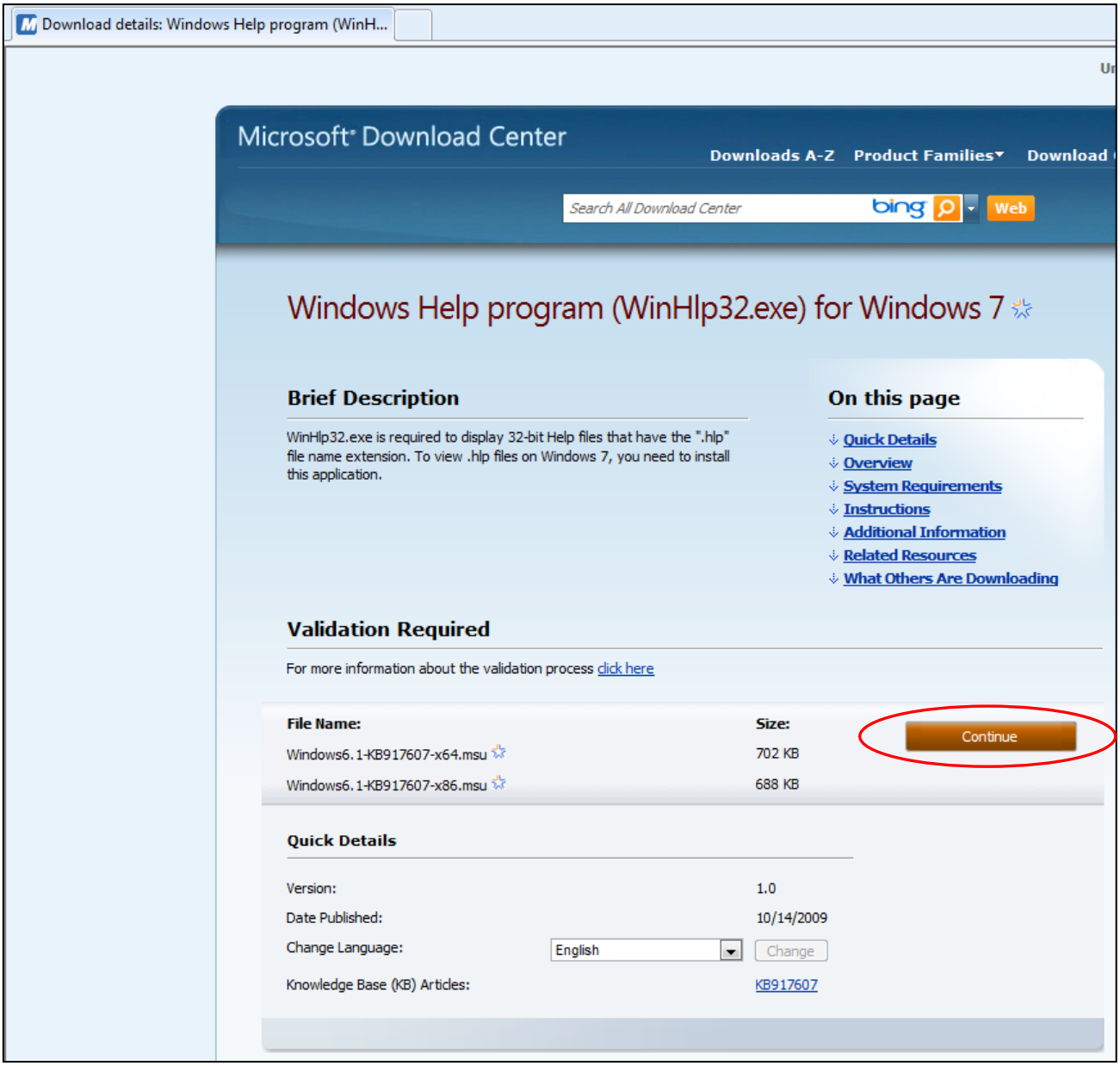

Figure 2.14: Microsoft® Download Center

You will be forwarded to a web page with instructions on how to install the Genuine Windows Validation Component.

At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.15).

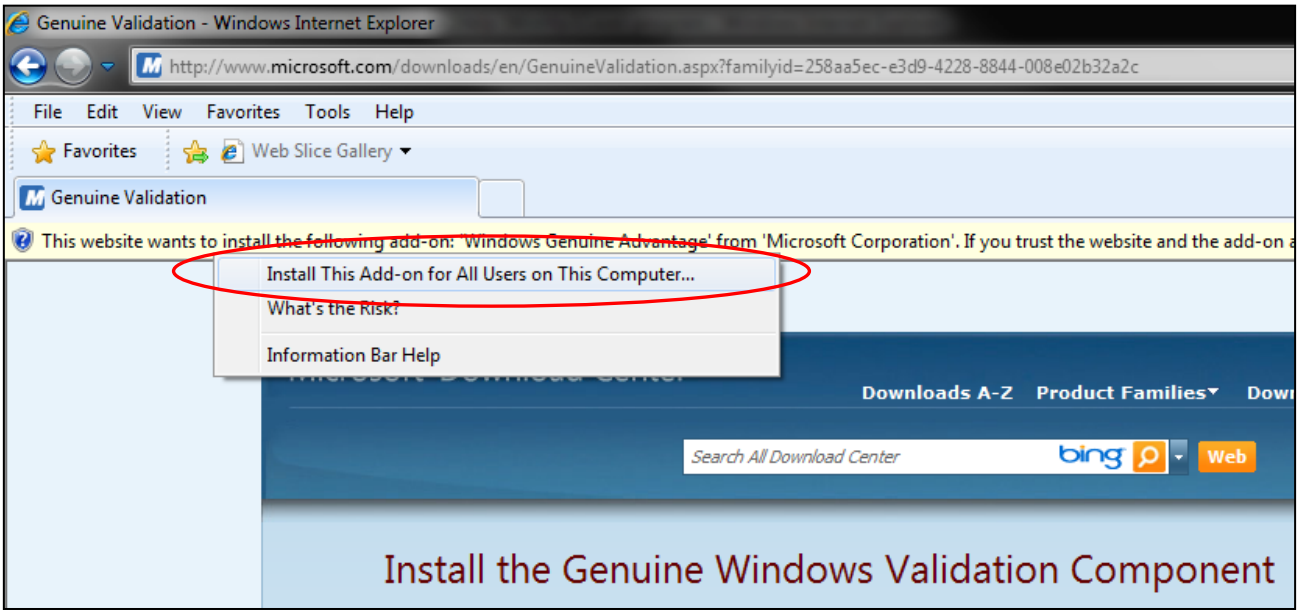

Figure 2.15: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.16).

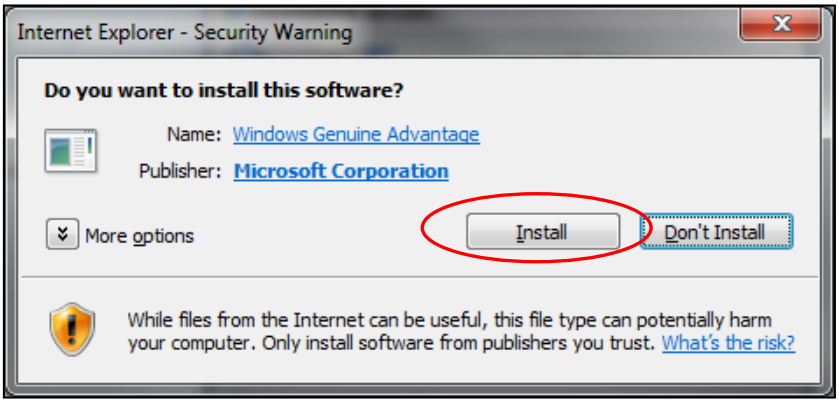

Figure 2.16: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.17).

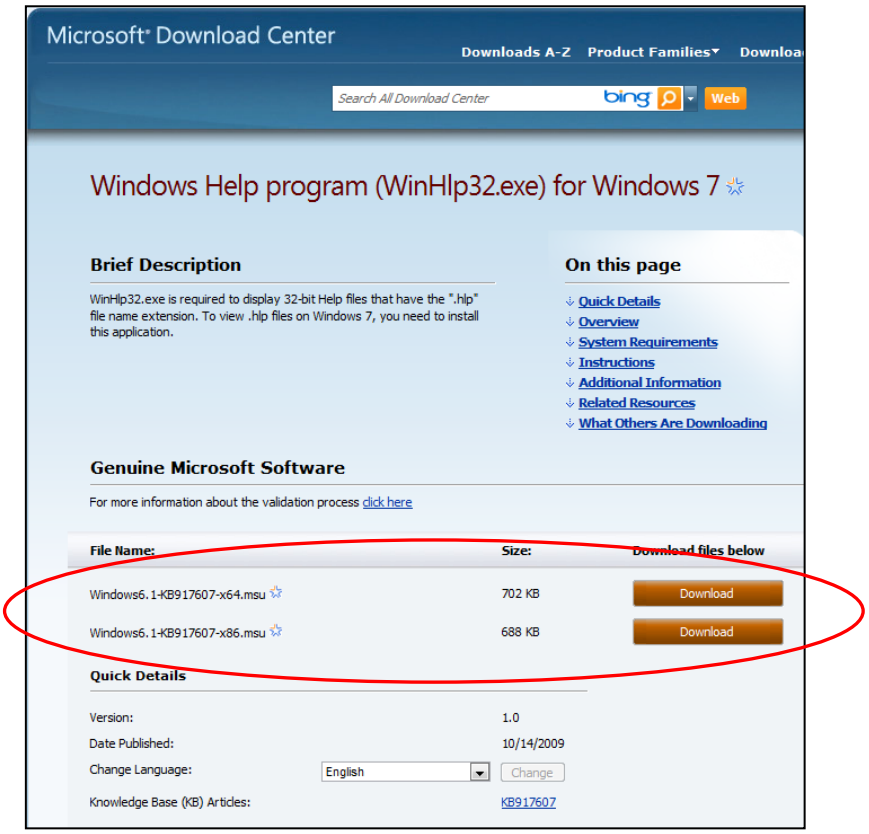

Figure 2.17: Downloading the Windows Help program

To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

If you are running a 64-bit operating system, please download the file

Windows6.1-KB917607-x64.msu.

If you are running a 32-bit operating system, please download the file

Windows6.1-KB917607-x86.msu.

In order to run the installation of the Windows Help program double-click the file you have just downloaded on your computer:

Windows6.1-KB917607-x64.msu	(for 64-bit operating system)
Windows6.1-KB917607-x86.msu.	(for 32-bit operating system).

Installation starts with a window searching for updates on your computer. After the program has finished searching you may see the following window.

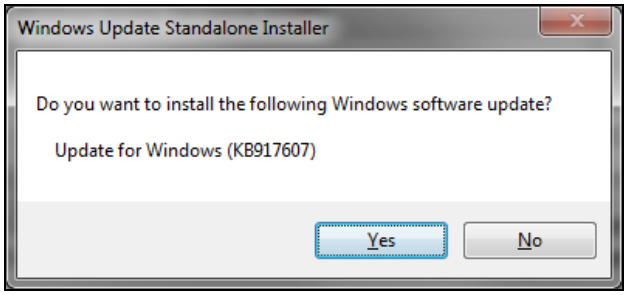

Figure 2.18: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button. (If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.") In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.19)

Figure 2.19: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.20).

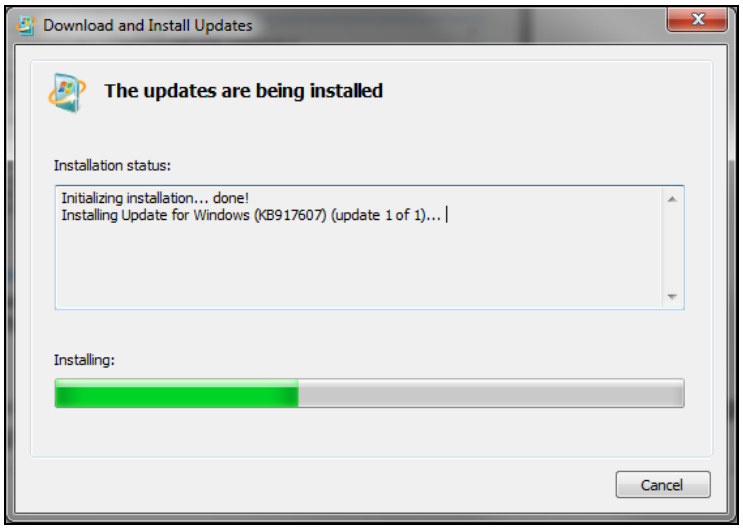

Figure 2.20: Installation process

After the Windows Help program has been installed, the notification "Installation complete" will appear. Confirm this by clicking the "Close" button.

The installation of the Windows Help program has been completed and you will now be able to open the Help files.

2.4 Licensing the LibC5H12_NEO Property Library

The licensing procedure has to be carried out when Excel® starts up and a FluidEXL*Graphics* prompt message appears. In this case, you will see the "License Information" window (see figure below).

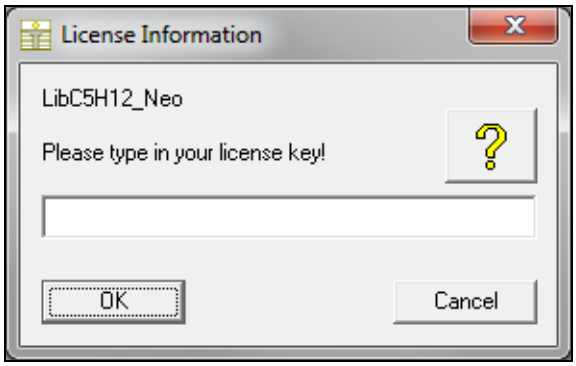

Figure 2.21: "License Information" window

Here you will have to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. You can find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:

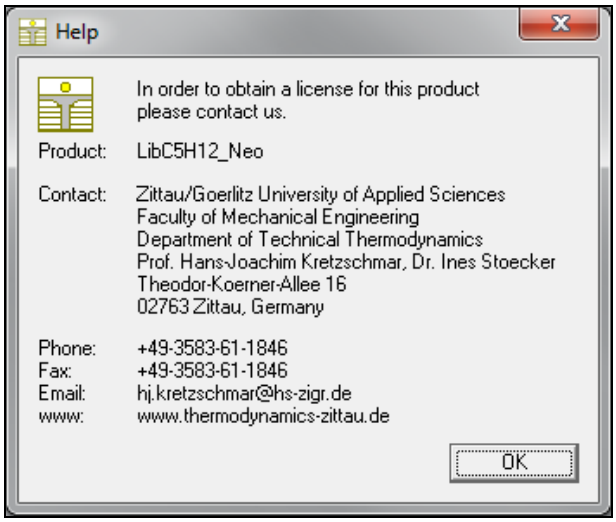

Figure 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel" twice. In this case, the LibC5H12_NEO property library will display the result "–11111111" for every calculation. The "License Information" window will appear every time you start Excel unless you uninstall FluidEXL*Graphics* according to the description in section 2.6 of this User's Guide. Should you not wish to license the LibC5H12_NEO property library, you have to delete the files

LibC5H12_NEO.dll
LibC5H12_NEO.hlp

in the installation folder of FluidEXL*Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows))

using an appropriate program such as Explorer® or Norton Commander.

2.5 Example: Calculation of *h* = f(*p*,*t*,*x*)

Now we will calculate, step by step, the specific enthalpy *h* as a function of pressure *p*, temperature *t*, and vapor fraction *x*, using FluidEXL*Graphics*.

- Start Excel®
- Enter a value for *p* in bar in a cell
  (Range of validity: p_t = 0.354009 bar to 2000 bar)

  ⇒ e. g.: Enter the value 10 into cell A2

- Enter a value for *t* in °C in a cell
  (Range of validity: t = - 15.55 °C to 276.85 °C)

  ⇒ e. g.: Enter the value 200 into cell B2

- Enter a value for *x* in kg saturated steam/kg wet steam in a cell

  Since the wet steam region is calculated automatically by the subprograms, the following fixed details on the vapor fraction *x* are to be considered when the value for *x* is entered:

  <u>Single-phase region</u>

  If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

  <u>Wet-steam region</u>

  If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.
  If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.
  When calculating wet steam either the given value for *t* and p = -1000 or the given value for *p* and t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.
  If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve.

  (Vapor-pressure curve of ethanol: t_{min} = - 15.55 °C to t_c = 160.59 °C
  p_{min} = 0.354009 bar to p_c = 31.9631 bar

  ⇒ e.g.: Enter –1 into the C2 cell.

- Click the cell in which the enthalpy *h* in kJ/kg is to be displayed.

  ⇒ e.g.: Click the D2 cell.

- Click "Calculate" in the menu bar of FluidEXL*Graphics*.
  Now the "Insert Function" window appears (see Figure 2.23).

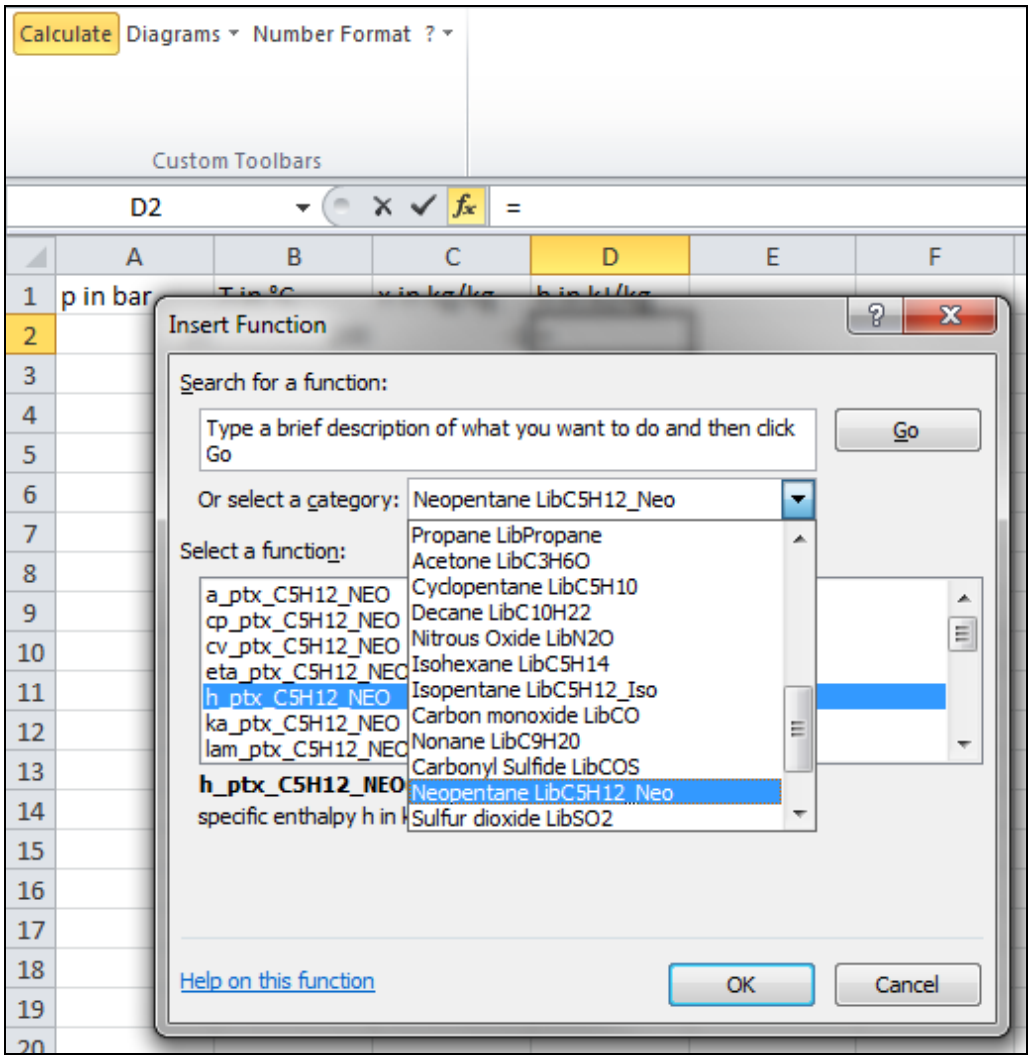

Figure 2.23: Choice of library and function name

- Search and click the "Neopentane LibC5H12_NEO" library under "Or select a category:" in the upper part of the window.
- Search and click the h_ptx_C5H12_NEO function under "Select a function:" right below.

  Here it is possible to get more information on the range of validity, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click "OK".
  The window shown in the next figure will now appear.

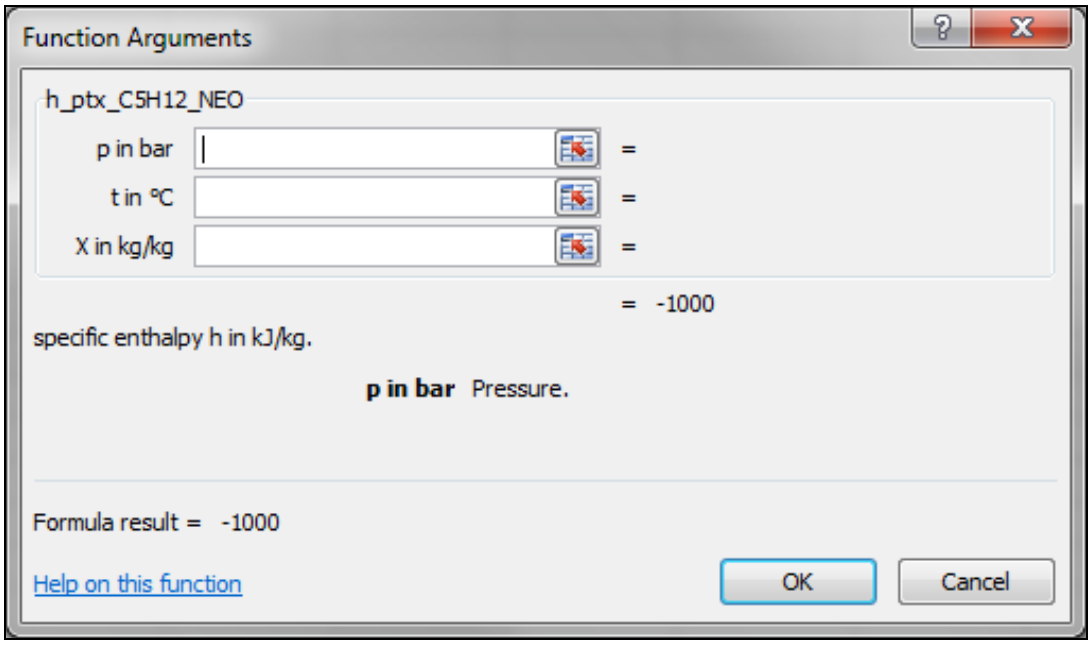

Figure 2.24: Input menu for the function

- The Cursor is now situated on the line next to " p in bar ". You can now enter the value for *p* either by clicking the cell with the value for *p* by entering the name of the cell with the value for *p*, or by entering the value for *p* directly.

  ⇒ e. g.: Click on the cell A2

- Situate the cursor next to "t in °C" and enter the value for *t* by clicking the cell with the value for *t,* by entering the name of the cell with the value for *t,* or by entering the value for *t* directly.

⇒ e. g.: Type B2 into the window next to "p"

- Situate the cursor next to "x in kg/kg" and enter the value for *x* by clicking the cell with the value for x, by entering the name of the cell with the value for *x*, or by entering the value for *x* directly.

  ⇒ e. g.: Click on the cell C2

  The window should now look like the following figure:

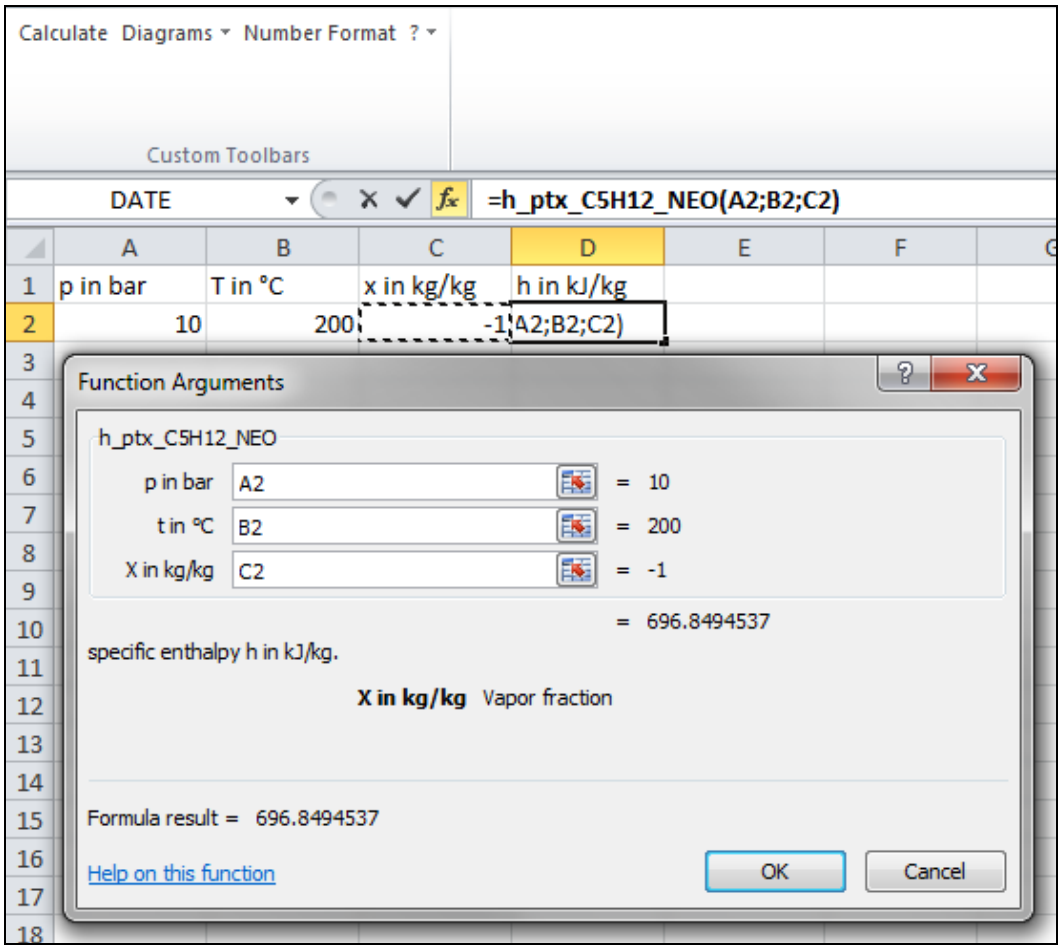

Figure 2.25: Input menu showing the result

- Click the "OK" button.
  The result for *h* in kJ/kg appears in the cell selected above.

  ⇒ The result for *h* in our sample calculation here is: 696.8494537 kJ/kg.

The calculation of $h = f(p,t,x)$ has been carried out. You can now arbitrarily change the values for *p*, *t* or *x* in the appropriate cells. This shows that the Excel® data flow and the DLL calculations are working together successfully.

Note:

If the calculation results in –1000, this indicates that the values entered are located outside the range of validity shown in Chapter 1. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL*Graphics*, see the function table in Chapter 1.

2.6 Removing FluidEXL*Graphics*

Should you wish to remove only the LibC5H12_NEO library, delete the files

LibC5H12_NEO.dll
LibC5H12_NEO.hlp

in the directory selected for the installation of FluidEXL*Graphics* (in the standard case

C:\Programme\FluidEXL_Graphics

by using an appropriate program such as Explorer®, Windows, or Norton Commander.

Unregistering FluidEXL*Graphics* as Add-In in Excel®, versions 2003 or earlier

To remove FluidEXL*Graphics* completely, proceed as follows: First the registration of

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)

has to be cancelled in Excel®.

In order to do that, click "Tools" in the upper menu bar of Excel and here "Add-Ins…". Untick the box on the left-hand side of

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows)

in the window that appears and click the "OK" button. The additional menu bar of FluidEXL*Graphics* disappears from the upper part of the Excel window. Afterwards, we recommend closing Excel.

If the FluidEXL*Graphics* menu bar does not disappear, take the following steps:
Click "View" in the upper menu bar of Excel, then "Toolbars" and then "Customize…" in the list box which appears.

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows),

is situated at the bottom of the "Toolbars" entries, which must be selected by clicking on it. Delete the entry by clicking "Delete". You will be asked whether you really want to delete the toolbar – click "OK".

Within the next step delete the files

LibC5H12_NEO.dll,
LibC5H12_NEO.hlp

in the directory selected for the installation of FluidEXL*Graphics* (in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows),

using an appropriate program such as Explorer® or Norton Commander.

In order to remove FluidEXL*Graphics* from Windows and the hard disk drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel". Now double-click on "Add or Remove Programs". In the list box of the "Add/Remove Programs" window that appears select

"FluidEXL Graphics Eng"	(for English version of Windows)
"FluidEXL Graphics"	(for German version of Windows)

by clicking on it and click the "Add/Remove…" button. In the following dialog box click "Automatic" and thereafter "Next >". Click "Finish" in the "Perform Uninstall" window. Answer the question whether all shared components shall be removed with "Yes to All". Finally, close the "Add/Remove Programs" and "Control Panel" windows.

Now FluidEXL*Graphics* has been removed.

Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007 (or later versions)

In order to unregister the FluidEXL*Graphics* Add-In in Excel® 2007 start Excel and carry out the following commands:

- Click the Windows Office® button in the upper left corner of Excel
- Click on the "Excel Options" button in the menu which appears

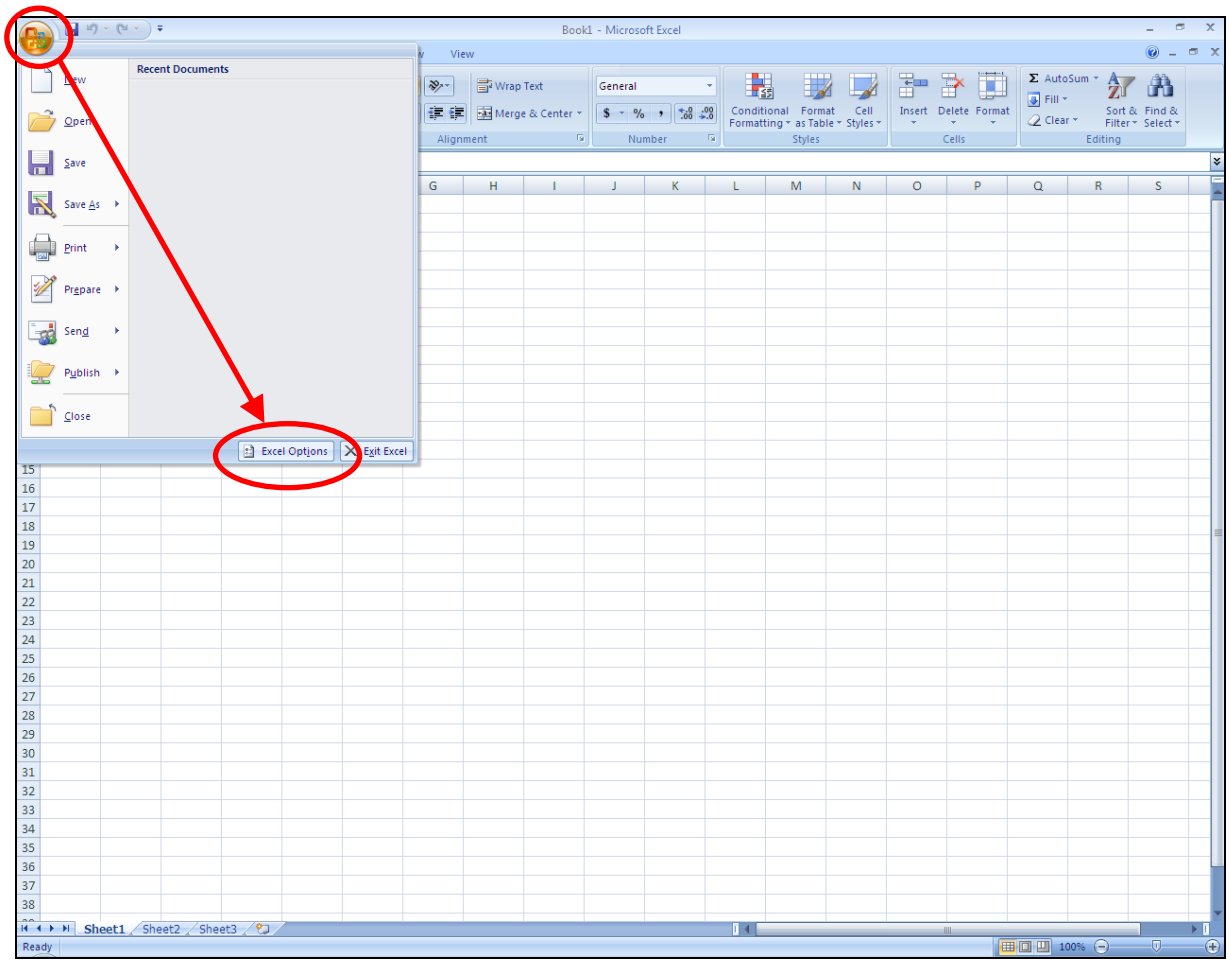

Figure 2.28: Unregistering FluidEXL*Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

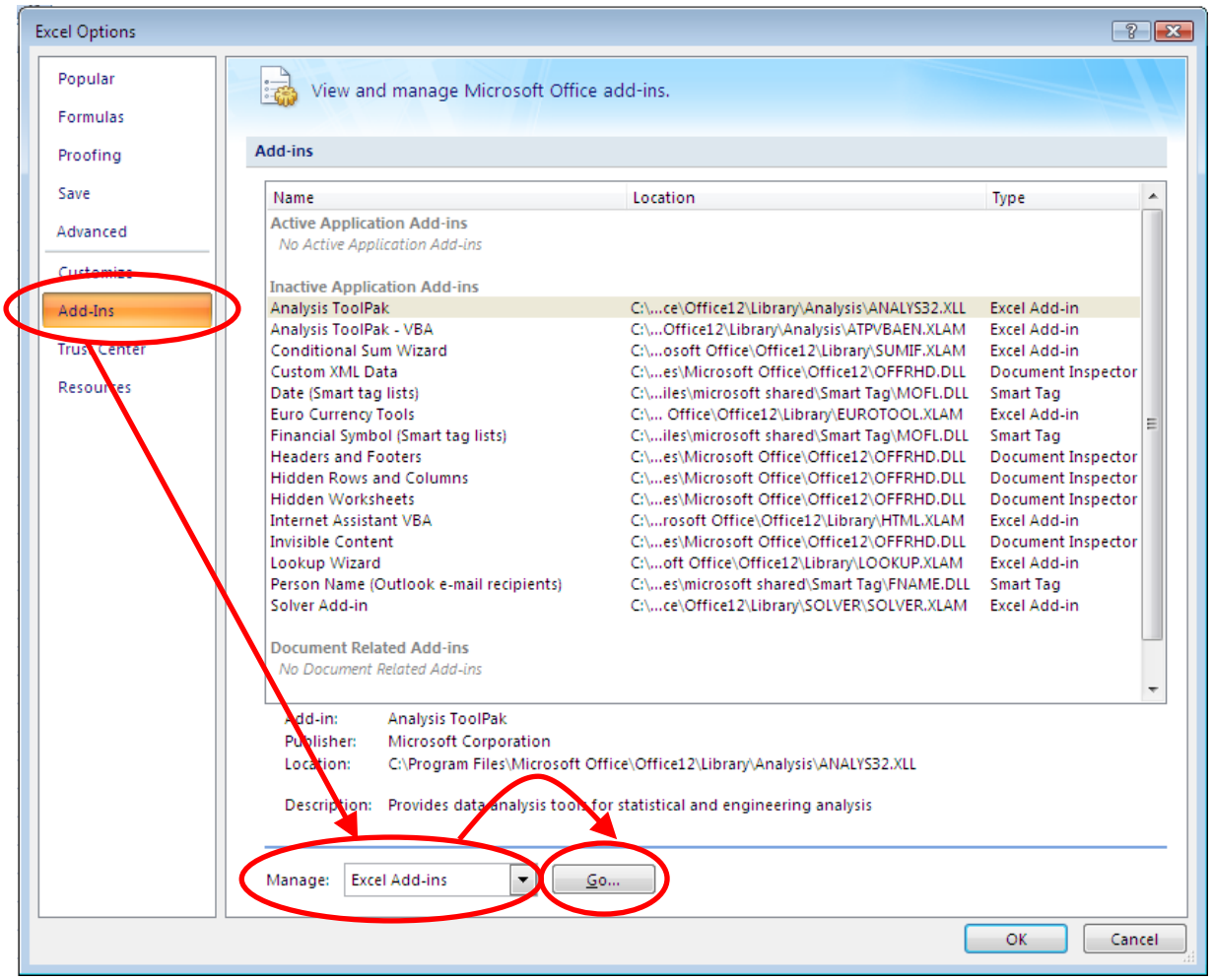

Figure 2.29: Dialog window "Add-Ins"

- If it is not shown in the list automatically, chose and click "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Afterwards click the "Go…" button
- Remove the checkmark in front of

  "FluidEXL Graphics Eng" (for English version of Windows)

  "FluidEXL Graphics" (for German version of Windows)

  in the window which now appears. Click the "OK" button to confirm your entry.

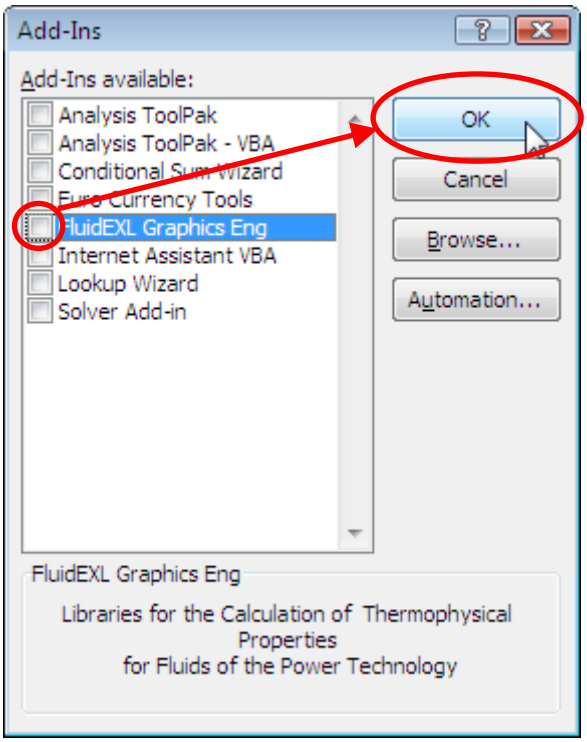

Figure 2.30: Dialog window "Add-Ins"

In order to remove FluidEXL*Graphics* from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel."

Now, double click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" window that appears, select

"FluidEXL Graphics Eng" (for English version of Windows)

"FluidEXL Graphics" (for German version of Windows)

by clicking on it and then clicking the "Add/Remove…" button.

Click "Automatic" in the following dialog box and then the "Next >" button.

Click "Finish" in the "Perform Uninstall" window.

Answer the question of whether all shared components should be removed with "Yes to All." Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidEXL*Graphics* has been completely removed from your computer.

3. Program Documentation

Thermal Diffusivity *a* = f (*p*,*t*,*x*)

Function Name: **a_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION A_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

a_ptx_C5H12_NEO or A_PTX_C5H12_NEO - Thermal diffusivity $a = \frac{\lambda}{\rho \cdot c_p} = \frac{\lambda \cdot v}{c_p}$ in m²/s

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **A_PTX_C5H12_NEO = –1000 or a_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and $t < t_{min}$ or $t > t_c$
- at t = –1000 and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1], [2], [3], [4], [6]

Specific Isobaric Heat Capacity c_p = f(p,t,x)

Function Name:	**cp_ptx_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION CP_PTX_C5H12_NEO (P, T, X)**
for call from Fortran	REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

cp_ptx_C5H12_NEO or CP_PTX_C5H12_NEO - Specific isobaric heat capacity cp in kJ/ (kg K)

Range of validity

Temperature range:	from - 15.55 °C to 276.85 °C
Pressure range:	from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **CP_PTX_C5H12_NEO = –1000 or cp_ptx_C5H12_NEO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Specific Isochoric Heat Capacity c_v = f(p,t,x)

Function Name: **cv_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION CV_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

cv_ptx_C5H12_NEO or CV_PTX_C5H12_NEO - Specific isochoric heat capacity cv in kJ/ (kg K)

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **CV_PTX_C5H12_NEO = –1000 or cv_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Dynamic Viscosity η = f(p,t,x)

Function Name:	**eta_ptx_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION ETA_PTX_C5H12_NEO (P, T, X)**
for call from Fortran	REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

eta_ptx_C5H12_NEO or ETA_PTX_C5H12_NEO - Dynamic viscosity η in Pa s

Range of validity

Temperature range:	from - 15.55 °C to 276.85 °C
Pressure range:	from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **ETA_PTX_C5H12_NEO = –1000 or eta_ptx_C5H12_NEO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [2], [3], [5], [6]

Specific Enthalpy *h* = f(*p*,*t*,*x*)

Function Name:	**h_ptx_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION H_PTX_C5H12_NEO (P, T, X)**
for call from Fortran	REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

h_ptx_C5H12_NEO or H_PTX_C5H12_NEO – specific enthalpy h in kJ/kg

Range of validity

Temperature range:	from - 15.55 °C to 276.85 °C
Pressure range:	from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **H_PTX_C5H12_NEO = –1000 or h_ptx_C5H12_NEO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Isentropic Exponent κ = f(p,t,x)

Function Name:	**ka_ptx_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION KA_PTX_C5H12_NEO (P, T, X)**
for call from Fortran	REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ka_ptx_C5H12_NEO or KA_PTX_C5H12_NEO – Isentropic exponent κ

Range of validity

Temperature range:	from - 15.55 °C to 276.85 °C
Pressure range:	from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **KA_PTX_C5H12_NEO = –1000 or ka_ptx_C5H12_NEO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and $t < t_{min}$ or $t > t_c$
- at t = –1000 and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1]

Thermal Conductivity λ = f(p,t,x)

Function Name: **lam_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION LAM_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

lam_ptx_C5H12_NEO or LAM_PTX_C5H12_NEO – Thermal conductivity λ in W/(m K)

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **LAM_PTX_C5H12_NEO = –1000 or lam_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and $t < t_{min}$ or $t > t_c$
- at t = –1000 and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1], [2], [3], [4], [6]

Kinematic Viscosity v = f(p,t,x)

Function Name: **ny_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION NY_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

ny_ptx_C5H12_NEO or NY_PTX_C5H12_NEO – Kinematic viscosity v in m²/s

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **NY_PTX_C5H12_NEO = –1000 or ny_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1], [2], [3], [5], [6]

Prandtl-Number Pr = f(*p*,*t*,*x*)

Function Name: **pr_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION PR_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

pr_ptx_C5H12_NEO or PR_PTX_C5H12_NEO -Prandtl-number- $\mathrm{Pr} = \frac{\eta \cdot c_p}{\lambda}$

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **PR_PTX_C5H12_NEO = –1000 or pr_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and $t < t_{min}$ or $t > t_c$
- at t = –1000 and $p < p_{min}$ or $p > p_c$
- at $p < p_{min}$ or $p > p_c$ or at $t < t_{min}$ or $t > t_c$

References: [1], [2], [3], [4], [5], [6]

Vapor Pressure p_s = f(t)

Function Name:	**ps_t_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION PS_T_C5H12_NEO (T)**
for call from Fortran	REAL*8 T

Input values

T - Temperature *t* in °C

Result

ps_t_C5H12_NEO or PS_T_C5H12_NEO - Vapor pressure p_s in bar

Range of validity

Temperature range: from t_{min} = - 15.55 °C to t_c = 160.59 °C

Results for wrong input values

Result **PS_T_C5H12_NEO = –1000 or ps_t_C5H12_NEO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

- at $t < t_{min}$ or $t > t_c$

References: [1]

Density ρ = f(p,t,x)

Function Name: **rho_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION RHO_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x in (kg saturated steam)/(kg wet steam)

Result

rho_ptx_C5H12_NEO or RHO_PTX_C5H12_NEO - Density ρ in kg/m³

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **RHO_PTX_C5H12_NEO = –1000 or rho_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Specific Entropy *s* = f(*p*,*t*,*x*)

Function Name: **s_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION S_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

s_ptx_C5H12_NEO or S_PTX_C5H12_NEO – specific entropy s in kJ/(kg K)

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **S_PTX_C5H12_NEO = –1000 or s_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Backward Function: Temperature *t* = f(*p*,*h*)

Function Name:	**t_ph_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION T_PH_C5H12_NEO (P, H)**
for call from Fortran	REAL*8 P,H

Input values

P - Pressure *p* in bar

H – Specific enthalpy h in kJ/kg

Result

t_ph_C5H12_NEO or T_PH_C5H12_NEO – Temperature t in °C

Range of validity

Temperature range:	from - 15.55 °C to 276.85 °C
Pressure range:	from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **T_PH_C5H12_NEO = –1000 or t_ph_C5H12_NEO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Backward Function: Temperature *t* = f(*p*,*s*)

Function Name:	**t_ps_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION T_PH_C5H12_NEO (P, s)**
for call from Fortran	REAL*8 P,S

Input values

p - Pressure *p* in bar

s – Specific entropy s in kJ/ (kg K)

Result

t_ps_C5H12_NEO or T_PS_C5H12_NEO – Temperature t in °C

Range of validity

Temperature range:	from - 15.55 °C to 276.85 °C
Pressure range:	from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **T_PS_C5H12_NEO = –1000 or t_ps_C5H12_NEO = –1000** for input values:

Single phase region:

Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Saturation Temperature t_s = f(p)

Function Name:	**ts_p_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION TS_P_C5H12_NEO (P)**
for call from Fortran	REAL*8 P

Input values

P - Pressure p in bar

Result

ts_t_C5H12_NEO or TS_P_C5H12_NEO - Saturation temperature t_s in °C

Range of validity

Pressure range: from p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **TS_P_C5H12_NEO = –1000 or ts_p_C5H12_NEO = –1000** for input values:

Wet steam region (0 ≤ x ≤ 1):

- at $p < p_{min}$ or $p > p_c$

References: [1]

Specific Internal Energy *u* = f(*p*,*t*,*x*)

Function Name: **u_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION U_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

u_ptx_C5H12_NEO or U_PTX_C5H12_NEO – specific internal energy u in kJ/kg

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **U_PTX_C5H12_NEO = –1000 or u_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Specific Volume *v* = f(*p*,*t*,*x*)

Function Name: **v_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION V_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

v_ptx_C5H12_NEO or V_PTX_C5H12_NEO – specific volume v in m³/kg

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **V_PTX_C5H12_NEO = –1000 or v_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at x < 0 or x > 1
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Isentropic Speed of Sound *w* = f(*p*,*t*,*x*)

Function Name: **w_ptx_C5H12_NEO**

Sub-program with function value: **REAL*8 FUNCTION W_PTX_C5H12_NEO (P, T, X)**
for call from Fortran REAL*8 P,T,X

Input values

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* in (kg saturated steam)/(kg wet steam)

Result

w_ptx_C5H12_NEO or W_PTX_C5H12_NEO – isentropic speed of sound w in m/s

Range of validity

Temperature range: from - 15.55 °C to 276.85 °C
Pressure range: from 0.354009 bar to 2000 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* and p = -1000, or the given value for *p* and t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* and *t* and *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Wet steam region:	Temperature ranges from	t_{min} = - 15.55 °C to t_c = 160.59 °C
	Pressure ranges from	p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **W_PTX_C5H12_NEO = –1000 or w_ptx_C5H12_NEO = –1000** for input values:

Single phase region:
Liquid or overheated steam (x = –1):
- at p < 0.354009 bar or p > 2000 bar
- at t < - 15.55 °C or t > 276.85 °C

Wet steam region (0 ≤ x ≤ 1):
- at 0 < x < 1 , i.e. calculation in the wet steam region not possible!
- at p = –1000 and t < t_{min} or t > t_c
- at t = –1000 and p < p_{min} or p > p_c
- at p < p_{min} or p > p_c or at t < t_{min} or t > t_c

References: [1]

Backward Funtion: Vapor Fraction *x* = f(*p*,*h*)

Function Name:	**x_ph_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION X_PH_C5H12_NEO (P, H)**
for call from Fortran	REAL*8 P,H

Input values

P - Pressure *p* in bar

H – Specific enthalpy h in kJ/kg

Result

x_ph_C5H12_NEO or X_PH_C5H12_NEO – Vapor fraction x in kg/kg

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically. This means that from the given values of *p* and *h* the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result x = - 1 will be returned.

Wet steam region: Pressure ranges from p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **X_PH_C5H12_NEO = –1 or x_ph_C5H12_NEO = –1** for input values:

- at x < 0 or x > 1
- at p < p_{min} or p > p_c
- at t < t_{min} or t > t_c

References: [1]

Backward Funtion: Vapor Fraction *x* = f(*p*,*s*)

Function Name:	**x_ps_C5H12_NEO**
Sub-program with function value:	**REAL*8 FUNCTION X_PH_C5H12_NEO (P, S)**
for call from Fortran	REAL*8 P,S

Input values

P - Pressure *p* in bar

S – Specific entropy s in kJ/ (kg K)

Result

x_ps_C5H12_NEO or X_PS_C5H12_NEO – Vapor fraction x in kg/kg

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically. This means that from the given values of *p* and *h* the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result x = - 1 will be returned.

Wet steam region: Pressure ranges from p_{min} = 0.354009 bar to p_c = 31.9631 bar

Results for wrong input values

Result **X_PS_C5H12_NEO = –1 or x_ps_C5H12_NEO = –1** for input values:

- at x < 0 or x > 1
- at p < p_{min} or p > p_c
- at t < t_{min} or t > t_c

References: [1]

ZITTAU/GOERLITZ UNIVERSITY OF APPLIED SCIENCES
Department of Technical Thermodynamics
www.thermodynamics-zittau.de

4. Property Libraries for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Water and Steam

Library LibIF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards
  - IAPWS-IF97-S01
  - IAPWS-IF97-S03rev
  - IAPWS-IF97-S04
  - IAPWS-IF97-S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

CO_2 - Span and Wagner	O_2 - Schmidt and Wagner
H_2O - IAPWS-95	Ar - Tegeler et al.
N_2 - Span et al.	

and of the ideal gases:

SO_2, CO, Ne (Scientific Formulation of Bücker et al.)

Consideration of:

Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

- Dry Air from Lemmon et al.
- Steam, water and ice from IAPWS-IF97 and IAPWS-06

Consideration of:

- Condensation and freezing of steam
- Dissociation from the VDI 4670
- Poynting effect from ASHRAE RP-1485

Carbon Dioxide including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1994)

Seawater

Library LibSeaWa

IAPWS Formulation 2008 of Feistel and IAPWS-IF97

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

Ar	NO	He	Propylene
Ne	H_2O	F_2	Propane
N_2	SO_2	NH_3	Iso-Butane
O_2	H_2	Methane	n-Butane
CO	H_2S	Ethane	Benzene
CO_2	OH	Ethylene	Methanol
Air			

Consideration of:

- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:

- Dissociation from the VDI Guideline 4670

Dry Air including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Nitrogen

Library LibN2

Formulation of Span et al. (2000)

Hydrogen

Library LibH2

Formulation of Leachman et al. (2007)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth (1995)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bücker et al. (2003)

n-Butane

Library LibButane_n

Formulation of Bücker et al. (2003)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

IAPWS Guideline 2001 of Tillner-Roth and Friend (1998)

Helmholtz energy equation for the mixing term

(also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethyl alcohol
CH_3OH	Methyl alcohol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate

Formulation of the International Institute of Refrigeration (1997)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ **Library LibD4**

Decamethylcyclopentasiloxane $C_{10}H_{30}O_5Si_5$ **Library LibD5**

Tetradecamethylhexasiloxane $C_{14}H_{42}O_5Si_6$ **Library LibMD4M**

Hexamethyldisiloxane $C_6H_{18}OSi_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $C_{12}H_{36}O_6Si_6$ **Library LibD6**

Decamethyltetrasiloxane $C_{10}H_{30}O_3Si_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $C_{12}H_{36}O_4Si_5$ **Library LibMD3M**

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ **Library LibMDM**

Formulation of Colonna et al. (2008)

Propane

Library LibPropane

Formulation of Lemmon et al. (2007)

Methanol

Library LibCH3OH

Formulation of de Reuck and Craven (1993)

Ethanol

Library LibC2H5OH

Formulation of Schroeder et al. (2012)

Helium

Library LibHe

Formulation of Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_5H_{14} **Library LibC5H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**

Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Dinitrogen monooxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Fax.: +49-3583-61-1846

The following thermodynamic and transport properties can be calculated[a]:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl-number Pr

Backward Functions

- T, v, s (p,h)
- T, v, h (p,s)
- p, T, v (h,s)
- p, T (v,h)
- p, T (v,u)

Thermodynamic Derivatives

- Partial derivatives can be calculated.

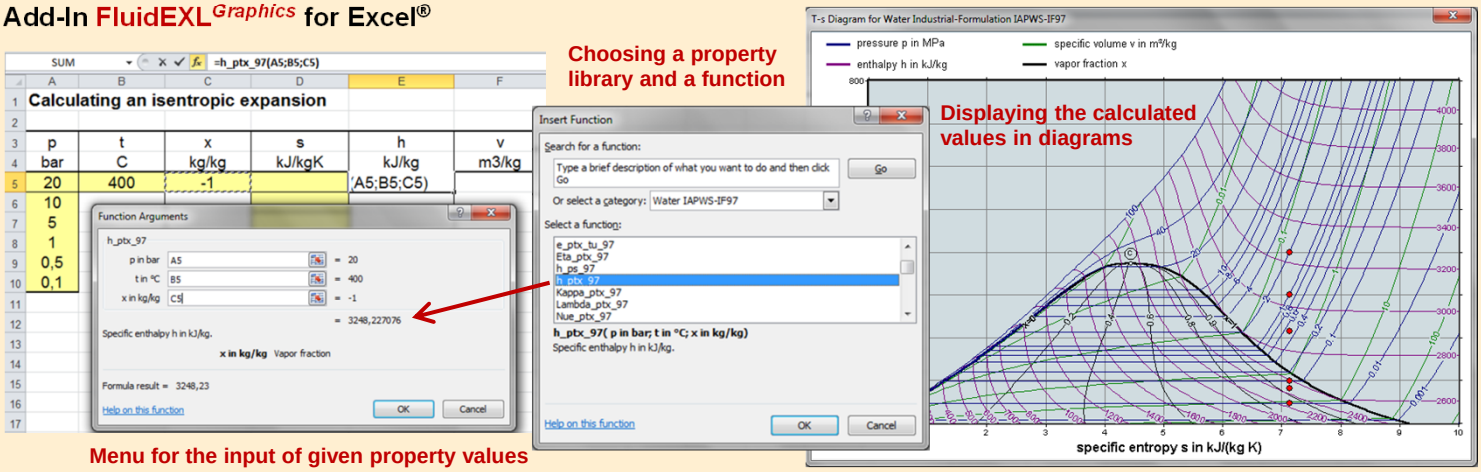
[a] Not all of these property functions are available in all property libraries.

www.thermodynamic-property-libraries.com

ZITTAU/GOERLITZ UNIVERSITY OF APPLIED SCIENCES
Department of Technical Thermodynamics
www.thermodynamics-zittau.de

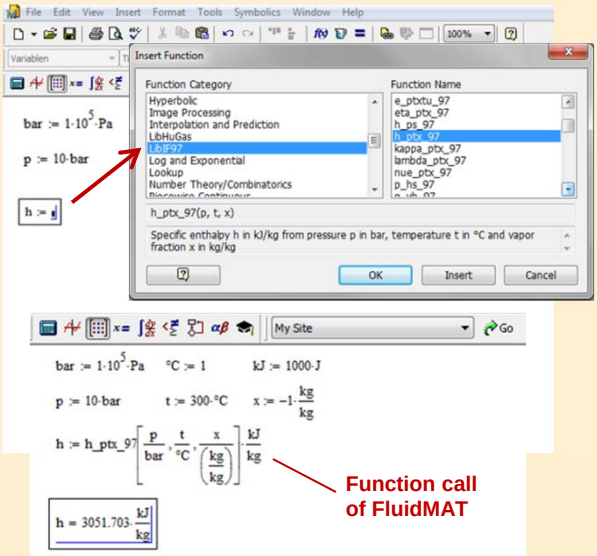
Property Software for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators

Add-In FluidEXL*Graphics* for Excel®



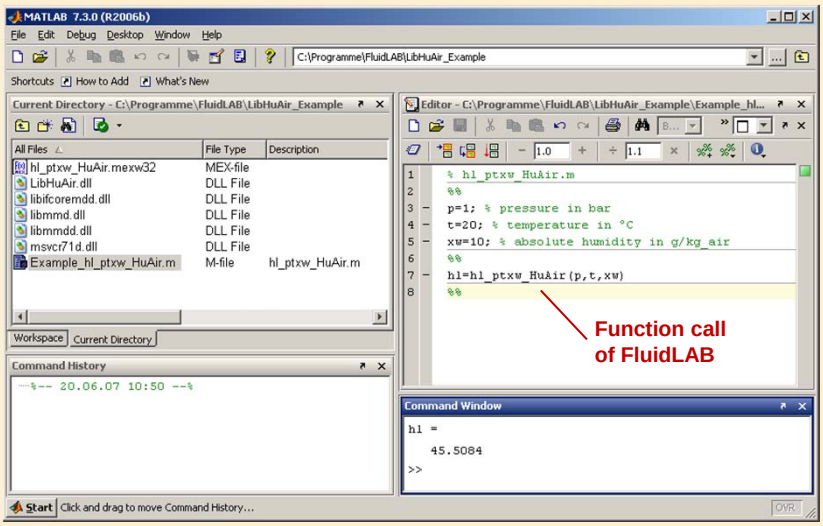
Add-In FluidMAT for Mathcad®

The property libraries can be used in Mathcad®.



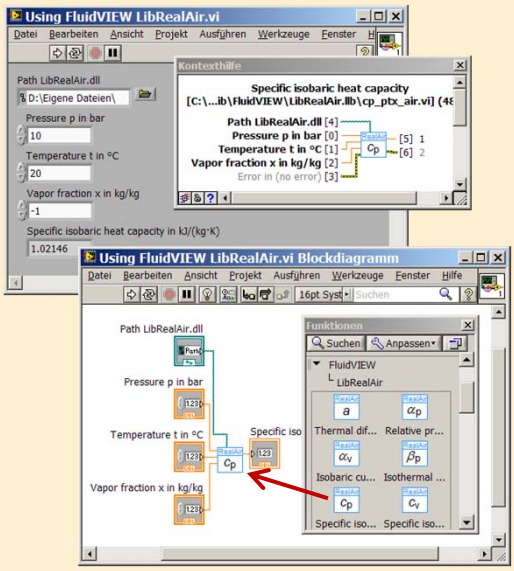
Add-In FluidLAB for MATLAB®

Using the Add-In FluidLAB the property functions can be called in MATLAB®.



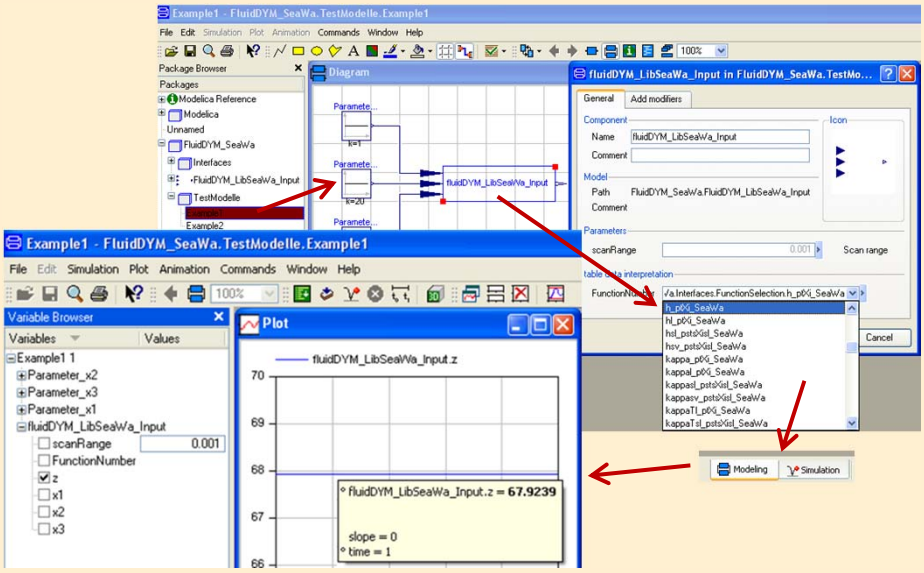
Add-On FluidVIEW for LabVIEW®

The property functions can be calculated in LabVIEW®.

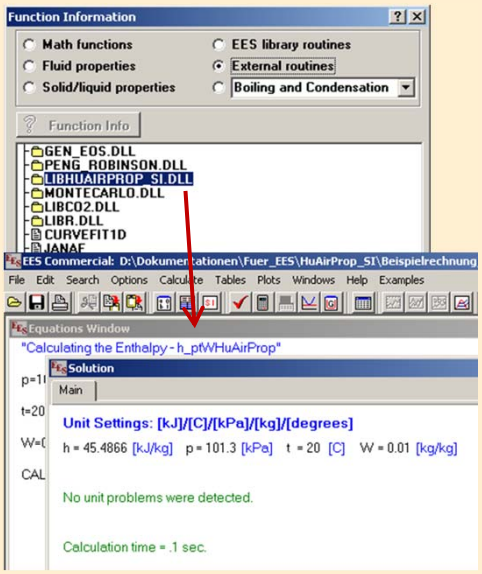


Add-In FluidDYM for DYMOLA® (Modelica) and SimulationX®

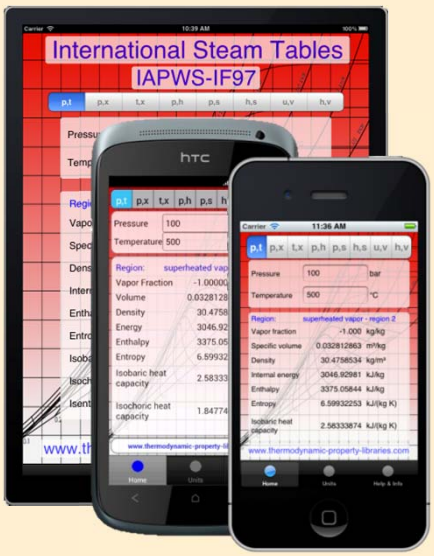
The property functions can be called in DYMOLA® and SimulationX®



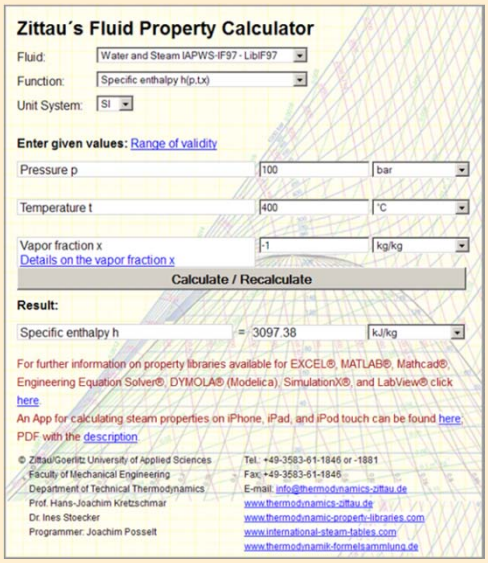
Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android smart phones and tablets



Online Property Calculator at www.thermodynamics-zittau.de



Property Software for Pocket Calculators

FluidCasio

fx 9750 G II | CFX 9850 fx-GG20 | CFX 9860 G Graph 85 | ALGEBRA FX 2.0

FluidHP

HP 48 | HP 49

FluidTI

TI 83, TI 84, TI 89 | TI Voyage 200 | TI 92

For more information please contact:

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Phone: +49-3583-61-1846
Fax.: +49-3583-61-1846

The following thermodynamic and transport properties[a] can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® EES, DYMOLA® (Modelica), SimulationX®, and LabVIEW®:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl-number Pr

Backward Functions

- T, v, s (p,h)
- T, v, h (p,s)
- p, T, v (h,s)
- p, T (v,h)
- p, T (v,u)

Thermodynamic Derivatives

- Partial derivatives can be calculated.

[a] Not all of these property functions are available in all property libraries.

www.thermodynamic-property-libraries.com

5. References

[1] E.W. Lemmon, R.Span:
Short Fundamental Equation of State for 20 Industrial Fluids
J.Chem.Eng.Data,51,p.785.850,2006

[2] M.L. Huber, A. Laeseck, R.A. Perkins,
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Including a New Correlation for the Viscosity of R134a
Ind. Eng. Chem. Res.,42, 3163-3178, 2003

[3] E.W. Lemmon:
Personal Communication with E.W. Lemmon, 2012

[4] K. Marsh, R. Perkins, M.L.V. Ramires:
Measurement and Correlation of the Thermal Conductivity of Propane
from 86 to 600 K at Pressures to 70 MPa
J. Chem. Eng. Data, 47(4), 932-940, 2002

[5] E. Vogel, C. Kuechenmeister, E. Bich, A. Laesecke:
Reference Correlation of the Viscosity of Propane
J. Phys. Chem. Ref. Data, 2, 947-970, 1998.

[6] E.W. Lemmon, M.O. McLinden, W. Wagner:
Thermodynamic Properties of Propane. III. A Reference Equation of State for
Temperatures from Melting Line to 650 K and Pressure up to 1000 MPa
J.Chem.Eng.Data, 54, 3141-3180, 2009

6. Satisfied Customers

Date: 10/2011

The following companies and institutions use the property libraries

- FluidEXL*Graphics* for Excel®
- FluidLAB for MATLAB®
- FluidMAT for Mathcad®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica)
- FluidVIEW for LabVIEW®:

2011

Lopez, Munguia, Spain	10/2011
University of KwaZulu-Natal, Westville, South Africa	10/2011
Voith, Heidenheim	09/2011
SpgBe Montreal, Canada	09/2011
SPG TECH, Montreuil Cedex, France	09/2011
Voith, Heidenheim-Mergelstetten	09/2011
MTU Aero Engines, Munich	08/2011
MIBRAG, Zeitz	08/2011
RWE, Essen	07/2011
Fels, Elingerode	07/2011
Weihenstephan University of Applied Sciences	07/2011, 09/2011, 10/2011
Forschungszentrum Juelich	07/2011
RWTH Aachen University	07/2011, 08/2011
INNEO Solutions, Ellwangen	06/2011
Caliqua, Basel, Switzerland	06/2011
Technical University of Freiberg	06/2011
Fichtner IT Consulting, Stuttgart	05/2011, 06/2011, 08/2011
Salzgitter Flachstahl, Salzgitter	05/2011
Helbling Beratung & Bauplanung, Zurich, Switzerland	05/2011
INEOS, Cologne	04/2011
Enseleit Consulting Engineers, Siebigerode	04/2011
Witt Consulting Engineers, Stade	03/2011

Helbling, Zurich, Switzerland	03/2011
MAN Diesel, Copenhagen, Denmark	03/2011
AGO, Kulmbach	03/2011
University of Duisburg	03/2011, 06/2011
CCP, Marburg	03/2011
BASF, Ludwigshafen	02/2011
ALSTOM Power, Baden, Switzerland	02/2011
Universität der Bundeswehr, Munich	02/2011
Calorifer, Elgg, Switzerland	01/2011
STRABAG, Vienna, Austria	01/2011
TUEV Sued, Munich	01/2011
ILK Dresden	01/2011
Technical University of Dresden	01/2011, 05/2011, 06/2011, 08/2011

2010

Umweltinstitut Neumarkt	12/2010
YIT Austria, Vienna, Austria	12/2010
MCI Innsbruck, Austria	12/2010
University of Stuttgart	12/2010
HS Cooler, Wittenburg	12/2010
Visteon, Novi Jicin, Czech Republic	12/2010
CompuWave, Brunntal	12/2010
Stadtwerke Leipzig	12/2010
MCI Innsbruck, Austria	12/2010
EVONIK Energy Services, Zwingenberg	12/2010
Caliqua, Basel, Switzerland	11/2010
Shanghai New Energy Resources Science & Technology, China	11/2010
Energieversorgung Halle	11/2010
Hochschule für Technik Stuttgart, University of Applied Sciences	11/2010
Steinmueller, Berlin	11/2010
Amberg-Weiden University of Applied Sciences	11/2010
AREVA NP, Erlangen	10/2010
MAN Diesel, Augsburg	10/2010
KRONES, Neutraubling	10/2010
Vaillant, Remscheid	10/2010

PC Ware, Leipzig	10/2010
Schubert Consulting Engineers, Weißenberg	10/2010
Fraunhofer Institut UMSICHT, Oberhausen	10/2010
Behringer Consulting Engineers, Tagmersheim	09/2010
Saacke, Bremen	09/2010
WEBASTO, Neubrandenburg	09/2010
Concordia University, Montreal, Canada	09/2010
Compañía Eléctrica de Sochagota, Bogota, Colombia	08/2010
Hannover University of Applied Sciences	08/2010
ERGION, Mannheim	07/2010
Fichtner IT Consulting, Stuttgart	07/2010
TF Design, Matieland, South Africa	07/2010
MCE, Berlin	07/2010, 12/2010
IPM, Zittau/Goerlitz University of Applied Sciences	06/2010
TUEV Sued, Dresden	06/2010
RWE IT, Essen	06/2010
Glen Dimplex, Kulmbach	05/2010, 07/2010 10/2010
Hot Rock, Karlsruhe	05/2010
Darmstadt University of Applied Sciences	05/2010
Voith, Heidenheim	04/2010
CombTec, Zittau	04/2010
University of Glasgow, Great Britain	04/2010
Universitaet der Bundeswehr, Munich	04/2010
Technical University of Hamburg-Harburg	04/2010
Vattenfall Europe, Berlin	04/2010
HUBER Consulting Engineers, Berching	04/2010
VER, Dresden	04/2010
CCP, Marburg	03/2010
Offenburg University of Applied Sciences	03/2010
Technical University of Berlin	03/2010
NIST Boulder CO, USA	03/2010
Technical University of Dresden	02/2010
Siemens Energy, Nuremberg	02/2010
Augsburg University of Applied Sciences	02/2010

ALSTOM Power, Baden, Switzerland	02/2010, 05/2010
MIT Massachusetts Institute of Technology Cambridge MA, USA	02/2010
Wieland Werke, Ulm	01/2010
Siemens Energy, Goerlitz	01/2010, 12/2010
Technical University of Freiberg	01/2010
ILK, Dresden	01/2010, 12/2010
Fischer-Uhrig Consulting Engineers, Berlin	01/2010

2009

ALSTOM Power, Baden, Schweiz	01/2009, 03/2009, 05/2009
Nordostschweizerische Kraftwerke AG, Doettingen, Switzerland	02/2009
RWE, Neurath	02/2009
Brandenburg University of Technology, Cottbus	02/2009
Hamburg University of Applied Sciences	02/2009
Kehrein, Moers	03/2009
EPP Software, Marburg	03/2009
Bernd Münstermann, Telgte	03/2009
Suedzucker, Zeitz	03/2009
CPP, Marburg	03/2009
Gelsenkirchen University of Applied Sciences	04/2009
Regensburg University of Applied Sciences	05/2009
Gatley & Associates, Atlanta, USA	05/2009
BOSCH, Stuttgart	06/2009, 07/2009
Dr. Nickolay, Consulting Engineers, Gommersheim	06/2009
Ferrostal Power, Saarlouis	06/2009
BHR Bilfinger, Essen	06/2009
Intraserv, Wiesbaden	06/2009
Lausitz University of Applied Sciences, Senftenberg	06/2009
Nuernberg University of Applied Sciences	06/2009
Technical University of Berlin	06/2009
Fraunhofer Institut UMSICHT, Oberhausen	07/2009
Bischoff, Aurich	07/2009
Fichtner IT Consulting, Stuttgart	07/2009
Techsoft, Linz, Austria	08/2009
DLR, Stuttgart	08/2009

Wienstrom, Vienna, Austria	08/2009
RWTH Aachen University	09/2009
Vattenfall, Hamburg	10/2009
AIC, Chemnitz	10/2009
Midiplan, Bietigheim-Bissingen	11/2009
Institute of Air Handling and Refrigeration ILK, Dresden	11/2009
FZD, Rossendorf	11/2009
Techgroup, Ratingen	11/2009
Robert Sack, Heidelberg	11/2009
EC, Heidelberg	11/2009
MCI, Innsbruck, Austria	12/2009
Saacke, Bremen	12/2009
ENERKO, Aldenhoven	12/2009

2008

Pink, Langenwang	01/2008
Fischer-Uhrig, Berlin	01/2008
University of Karlsruhe	01/2008
MAAG, Kuesnacht, Switzerland	02/2008
M&M Turbine Technology, Bielefeld	02/2008
Lentjes, Ratingen	03/2008
Siemens Power Generation, Goerlitz	04/2008
Evonik, Zwingenberg (general EBSILON program license)	04/2008
WEBASTO, Neubrandenburg	04/2008
CFC Solutions, Munich	04/2008
RWE IT, Essen	04/2008
Rerum Cognitio, Zwickau	04/2008, 05/2008
ARUP, Berlin	05/2008
Research Center, Karlsruhe	07/2008
AWECO, Neukirch	07/2008
Technical University of Dresden, Professorship of Building Services	07/2008
Technical University of Cottbus, Chair in Power Plant Engineering	07/2008, 10/2008
Ingersoll-Rand, Unicov, Czech Republic	08/2008
Technip Benelux BV, Zoetermeer, Netherlands	08/2008
Fennovoima Oy, Helsinki, Finland	08/2008

Fichtner Consulting & IT, Stuttgart	09/2008
PEU, Espenhain	09/2008
Poyry, Dresden	09/2008
WINGAS, Kassel	09/2008
TUEV Sued, Dresden	10/2008
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	10/2008, 11/2008
AWTEC, Zurich, Switzerland	11/2008
Siemens Power Generation, Erlangen	12/2008

2007

Audi, Ingolstadt	02/2007
ANO Abfallbehandlung Nord, Bremen	02/2007
TUEV NORD SysTec, Hamburg	02/2007
VER, Dresden	02/2007
Technical University of Dresden, Chair in Jet Propulsion Systems	02/2007
Redacom, Nidau, Switzerland	02/2007
Universität der Bundeswehr, Munich	02/2007
Maxxtec, Sinsheim	03/2007
University of Rostock, Chair in Technical Thermodynamics	03/2007
AGO, Kulmbach	03/2007
University of Stuttgart, Chair in Aviation Propulsions	03/2007
Siemens Power Generation, Duisburg	03/2007
ENTHAL Haustechnik, Rees	05/2007
AWECO, Neukirch	05/2007
ALSTOM, Rugby, Great Britain	06/2007
SAAS, Possendorf	06/2007
Grenzebach BSH, Bad Hersfeld	06/2007
Reichel Engineering, Haan	06/2007
Technical University of Cottbus, Chair in Power Plant Engineering	06/2007
Voith Paper Air Systems, Bayreuth	06/2007
Egger Holzwerkstoffe, Wismar	06/2007
Tissue Europe Technologie, Mannheim	06/2007
Dometic, Siegen	07/2007
RWTH Aachen University, Institute for Electrophysics	09/2007
National Energy Technology Laboratory, Pittsburg, USA	10/2007

Energieversorgung Halle	10/2007
AL-KO, Jettingen	10/2007
Grenzebach BSH, Bad Hersfeld	10/2007
Wiesbaden University of Applied Sciences, Department of Engineering Sciences	10/2007
Endress+Hauser Messtechnik, Hannover	11/2007
Munich University of Applied Sciences, Department of Mechanical Engineering	11/2007
Rerum Cognitio, Zwickau	12/2007
Siemens Power Generation, Erlangen	11/2007
University of Rostock, Chair in Technical Thermodynamics	11/2007, 12/2007

2006

STORA ENSO Sachsen, Eilenburg	01/2006
Technical University of Munich, Chair in Energy Systems	01/2006
NUTEC Engineering, Bisikon, Switzerland	01/2006, 04/2006
Conwel eco, Bochov, Czech Republic	01/2006
Offenburg University of Applied Sciences	01/2006
KOCH Transporttechnik, Wadgassen	01/2006
BEG Bremerhavener Entsorgungsgesellschaft	02/2006
Deggendorf University of Applied Sciences, Department of Mechanical Engineering and Mechatronics	02/2006
University of Stuttgart, Department of Thermal Fluid Flow Engines	02/2006
Technical University of Munich, Chair in Apparatus and Plant Engineering	02/2006
Energietechnik Leipzig (company license),	02/2006
Siemens Power Generation, Erlangen	02/2006, 03/2006
RWE Power, Essen	03/2006
WAETAS, Pobershau	04/2006
Siemens Power Generation, Goerlitz	04/2006
Technical University of Braunschweig, Department of Thermodynamics	04/2006
EnviCon & Plant Engineering, Nuremberg	04/2006
Brassel Engineering, Dresden	05/2006
University of Halle-Merseburg, Department of USET Merseburg incorporated society	05/2006
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	05/2006

Fichtner Consulting & IT Stuttgart (company licenses and distribution)	05/2006
Suedzucker, Ochsenfurt	06/2006
M&M Turbine Technology, Bielefeld	06/2006
Feistel Engineering, Volkach	07/2006
ThyssenKrupp Marine Systems, Kiel	07/2006
Caliqua, Basel, Switzerland (company license)	09/2006
Atlas-Stord, Rodovre, Denmark	09/2006
Konstanz University of Applied Sciences, Course of Studies Construction and Development	10/2006
Siemens Power Generation, Duisburg	10/2006
Hannover University of Applied Sciences, Department of Mechanical Engineering	10/2006
Siemens Power Generation, Berlin	11/2006
Zikesch Armaturentechnik, Essen	11/2006
Wismar University of Applied Sciences, Seafaring Department	11/2006
BASF, Schwarzheide	12/2006
Enertech Energie und Technik, Radebeul	12/2006

2005

TUEV Nord, Hannover	01/2005
J.H.K Plant Engineering and Service, Bremerhaven	01/2005
Electrowatt-EKONO, Zurich, Switzerland	01/2005
FCIT, Stuttgart	01/2005
Energietechnik Leipzig (company license)	02/2005, 04/2005, 07/2005
eta Energieberatung, Pfaffenhofen	02/2005
FZR Forschungszentrum, Rossendorf/Dresden	04/2005
University of Saarbruecken	04/2005
Technical University of Dresden Professorship of Thermic Energy Machines and Plants	04/2005
Grenzebach BSH, Bad Hersfeld	04/2005
TUEV Nord, Hamburg	04/2005
Technical University of Dresden, Waste Management	05/2005
Siemens Power Generation, Goerlitz	05/2005
Duesseldorf University of Applied Sciences, Department of Mechanical Engineering and Process Engineering	05/2005

Redacom, Nidau, Switzerland	06/2005
Dumas Verfahrenstechnik, Hofheim	06/2005
Alensys Engineering, Erkner	07/2005
Stadtwerke Leipzig	07/2005
SaarEnergie, Saarbruecken	07/2005
ALSTOM ITC, Rugby, Great Britain	08/2005
Technical University of Cottbus, Chair in Power Plant Engineering	08/2005
Vattenfall Europe, Berlin (group license)	08/2005
Technical University of Berlin	10/2005
Basel University of Applied Sciences, Department of Mechanical Engineering, Switzerland	10/2005
Midiplan, Bietigheim-Bissingen	11/2005
Technical University of Freiberg, Chair in Hydrogeology	11/2005
STORA ENSO Sachsen, Eilenburg	12/2005
Energieversorgung Halle (company license)	12/2005
KEMA IEV, Dresden	12/2005

2004

Vattenfall Europe (group license)	01/2004
TUEV Nord, Hamburg	01/2004
University of Stuttgart, Institute of Thermodynamics and Heat Engineering	02/2004
MAN B&W Diesel A/S, Copenhagen, Denmark	02/2004
Siemens AG Power Generation, Erlangen	02/2004
Ulm University of Applied Sciences	03/2004
Visteon, Kerpen	03/2004, 10/2004
Technical University of Dresden, Professorship of Thermic Energy Machines and Plants	04/2004
Rerum Cognitio, Zwickau	04/2004
University of Saarbruecken	04/2004
Grenzebach BSH, Bad Hersfeld	04/2004
SOFBID Zwingenberg (general EBSILON program license)	04/2004
EnBW Energy Solutions, Stuttgart	05/2004
HEW-Kraftwerk, Tiefstack	06/2004
h s energieanlagen, Freising	07/2004
FCIT, Stuttgart	08/2004
Physikalisch Technische Bundesanstalt (PTB), Braunschweig	08/2004
Mainova Frankfurt	08/2004

Rietschle Energieplaner, Winterthur, Switzerland	08/2004
MAN Turbo Machines, Oberhausen	09/2004
TUEV Sued, Dresden	10/2004
STEAG Kraftwerk, Herne	10/2004, 12/2004
University of Weimar	10/2004
energeticals (e-concept), Munich	11/2004
SorTech, Halle	11/2004
Enertech EUT, Radebeul (company license)	11/2004
Munich University of Applied Sciences	12/2004
STORA ENSO Sachsen, Eilenburg	12/2004
Technical University of Cottbus, Chair in Power Plant Engineering	12/2004
Freudenberg Service, Weinheim	12/2004

2003

Paper Factory, Utzenstorf, Switzerland	01/2003
MAB Plant Engineering, Vienna, Austria	01/2003
Wulff Energy Systems, Husum	01/2003
Technip Benelux BV, Zoetermeer, Netherlands	01/2003
ALSTOM Power, Baden, Switzerland	01/2003, 07/2003
VER, Dresden	02/2003
Rietschle Energieplaner, Winterthur, Switzerland	02/2003
DLR, Leupholdhausen	04/2003
Emden University of Applied Sciences, Department of Technology	05/2003
Petterssson+Ahrends, Ober-Moerlen	05/2003
SOFBID ,Zwingenberg (general EBSILON program license)	05/2003
Ingenieurbuero Ostendorf, Gummersbach	05/2003
TUEV Nord, Hamburg	06/2003
Muenstermann GmbH, Telgte-Westbevern	06/2003
University of Cali, Colombia	07/2003
Atlas-Stord, Rodovre, Denmark	08/2003
ENERKO, Aldenhoven	08/2003
STEAG RKB, Leuna	08/2003
eta Energieberatung, Pfaffenhofen	08/2003
exergie, Dresden	09/2003
AWTEC, Zurich, Switzerland	09/2003
Energie, Timelkam, Austria	09/2003

Electrowatt-EKONO, Zurich, Switzerland	09/2003
LG, Annaberg-Buchholz	10/2003
FZR Forschungszentrum, Rossendorf/Dresden	10/2003
EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

2002

Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
Bochum University of Applied Sciences, Department of Thermo- and Fluid Dynamics	01/2002
SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
FZR Forschungszentrum, Rossendorf/Dresden	03/2002
CompAir, Simmern	03/2002
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	05/2002
SoftSolutions, Muehlhausen (company license)	05/2002
DREWAG, Dresden (company license)	05/2002
SOFBID, Zwingenberg (general EBSILON program license)	06/2002
Kleemann Engineering, Dresden	06/2002
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002

Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

2001

ALSTOM Power, Baden, Switzerland	01/2001, 06/2001, 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001
Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

2000

SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000

IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
VEAG, Berlin (group license)	03/2000
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

1999

Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
KEMA IEV, Dresden	03/1999
Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

1998

Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
M&M Turbine Technology Bielefeld	06/1998
B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998

SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

1997

Gerb, Dresden	06/1997
Siemens Power Generation, Goerlitz	07/1997